AD-A152 054

Toward More Productive Naval Shipbuilding

Marine Board
Commission on Engineering and Technical Systems
National Research Council

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Committee on U.S. Shipbuilding Technology
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National Academy Press
Washington, D.C. 1984

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This report represents work supported by Department of the Navy Contract No. N00024-82-C-5349, and Contract No. DTMA91-83-C-30050 between the U.S. Department of Transportation and the National Academy of Sciences.

Limited copies are available from:
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PREFACE

At any time in this decade, the U.S. Navy will have about 100 combatant, auxiliary, and coastal patrol ships under construction or conversion, in as many as 24 private shipyards. The ship construction, conversion, and overhaul workload consumes about a sixth of the total Navy budget and construction and conversion provide about 100,000 direct labor jobs in the private shipyards. Since about two-thirds of the value of naval ship construction is contributed by the shipyards' suppliers,[1] the actual number of jobs dependent on Navy shipbuilding is several times the shipyard direct labor figure. The economic impact of naval shipbuilding reaches into nearly every state in the union. In addition to its size and economic importance, the shipbuilding and supplier industry is strategically important, and its continued health, including readiness for mobilization, is a matter of national importance.

However, the U.S. shipbuilding industry continues to be uncompetitive in commercial shipbuilding on a world scale. In fact, within the period of conducting this study, four of 27 shipyards in the (1981) active industrial base have closed.[2] The reasons for and implications of these developments are of concern to the Navy whose dependence on the industry is so great.

As an element of this concern, the Navy asked the National Research Council of the National Academy of Sciences in 1981 to identify promising technology developments that have the potential to improve the productivity of the U.S. shipbuilding industry. The National Research Council appointed the Committee on U.S. Shipbuilding Technology under its Marine Board to appraise the potential for shipyard productivity improvement through the introduction of technological, organizational, and management innovations.

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[1]This estimate is characteristic of a surface combatant.

[2]American Ship Building, Lorain, Oh.; Todd Shipyards, Houston, Tex.; Levingston Shipbuilding, Orange, Tex.; Sun Shipbuilding, Phil., Pa.

Members of the committee were selected for their experience in the development and application of productivity improvements in a corporate environment, industrial engineering, manufacturing and engineering of ship components, shipyard and supplier management, naval architecture and marine engineering, research and development management, and merchant and naval ship construction. The principle guiding the constitution of the committee and its work, consistent with the policy of the National Research Council, was not to exclude the bias that might accompany expertise vital to the study but to seek balance and fair treatment.

Productivity improvements were defined by the committee to include savings in time, cost, and total effort, improvements in the quality of the ships that are built, and the safety of the personnel involved. The committee assessed industrial engineering and automation technologies available in other industries that have the potential for shipbuilding technology improvements, opportunities and strategies for developing and implementing the next generation of shipbuilding technologies, and management strategies for shipbuilding technology developments.

The committee focused on new construction of both combatant and noncombatant Navy ships built by domestic, private shipbuilders. The 24 shipyards who are actively involved in the Navy's new construction program as well as their suppliers were studied. Private-sector ship overhaul and repair work and the Navy's public shipyards were not extensively treated. While the committee has emphasized productivity improvements in the building of U.S. naval ships, the committee believes that much of its work is also pertinent to the building of commercial ships, and to productivity improvement in the hundreds of smaller shipyards in the United States.

The committee was not asked to assess the adequacy of the shipbuilding and supplier industry for national mobilization, nor to make recommendations on how to safeguard this industrial base. Nevertheless, considerations of some of the technical issues within the committee's charge necessitated an understanding and analysis of this subject.

The committee devoted much of its first year to the identification and appraisal of issues in shipbuilding productivity. To this end, it convened a National Conference on Naval Shipbuilding Technology (June 1982) and a public symposium on computer-aided design and computer-aided manufacturing (CAD/CAM) applications in the construction of naval vessels (September 1982). The committee identified and appraised 17 major issues concerning the productivity of U.S. naval shipbuilding. Following the identification and appraisal of issues, the committee conducted detailed technical assessments of three of the issues it identified. These were: (1) computerization of design and manufacture, (2) shipbuilding standards, (3) productivity of the work force and attention to the working environment. A report was issued at the end of the first year, presenting the results of that phase of the study (National Research Council, 1982).

The Navy asked that additional technical assessments be made in a second-year effort, which commenced in September 1983. In the second

phase, the committee completed several additional technical assessments, and also evaluated the cross-cutting issues of industrial management, government policies and programs, and technology development. This report, the final report of the committee, presents the results of the second-year effort and also draws on the work of the first year.

The technical assessments undertaken in the second year and reported herein include capital formation, production management systems, integration of engineering and production to support ship construction, and supplier issues in Navy shipbuilding. The committee appointed special work groups of committee members and industry and government experts for each of the technical assessments. More than 40 volunteer experts served on the work groups. The membership of the work groups, and their findings, are presented in Appendix A. The findings of the work groups are included in their entirety in Appendix A, for completeness. Those particular findings endorsed by the committee have been carried forward into the report, including the conclusions and recommendations.

In addition to the work group meetings of those conducting the technical assessments, the committee met three times to complete its second-year agenda. At the meetings, it received information from industry and government experts on the status of the shipbuilding and supplier industry, focusing on productivity issues.

This report of the committee's second phase reflects a point of view that productivity improvements are more readily initiated by the customer (the Navy) than the manufacturer (the shipbuilder and shipbuilding supplier), who is in a position of responding to the customer's needs and demands. This is a manufacturing philosophy. As a result of this point of view, the Navy, to a greater extent than shipbuilders and suppliers, is the subject of constructive criticism, conclusions, and recommendations in this report.

The committee benefited greatly from, and acknowledges with gratitude, the contributions of those who served on the technical assessment work groups and other devoted individuals and interested organizations. Three U.S. naval shipbuilders participated in all of the committee's deliberations in the second phase--except the development of the committee's conclusions and recommendations--Peter Jaquith, Bath Iron Works; William O'Neill, Newport News Shipbuilding and Dry Dock Co.; and, Edwin Petersen, Todd Pacific Shipyards Corp., who was also chairman of the Ship Production Committee of the Society of Naval Architects and Marine Engineers. The Shipbuilders Council of America provided information to the committee and assisted in identifying industry experts. Richard Glenn, Jered Brown Bros., and Eugene Avallone, Gould, Inc., prepared presentations for the committee on the productivity of naval shipbuilding suppliers. J. J. Klohocker and Albert Mieskolainen of the NAVSEA Shipbuilding Support Office provided data on shipbuilding suppliers. Louis D. Chirillo of Louis D. Chirillo Associates graciously provided the committee with photographs. Raymond Ramsay, Director of the Office of Maritime Affairs, Naval Sea Systems Command, provided material and invaluable assistance and support throughout both phases of the committee's study.

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SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This summary of the final report of an assessment of conditions and change in the U.S. naval shipbuilding industry documents the considerable progress in improving productivity achieved by the Navy, its shipbuilders and suppliers in recent years, and identifies promising technological developments that have the potential to improve still further the productivity of the U.S. naval shipbuilding industry. Conducted by the National Research Council of the National Academy of Sciences, the study was done in two stages. In the first phase, 17 major issues were identified and appraised, and detailed technical assessments of several of the issues were undertaken.[1] This report completes the technical assessment of issues begun in the first phase, and incorporates the work of the first year to present a complete appraisal of opportunities for productivity improvement in U.S. naval shipbuilding.

This report of the committee's second phase reflects a point of view that productivity improvements are more readily initiated by the customer (the Navy) than the manufacturer (the shipbuilder and shipbuilding supplier), who is in a position of responding to the customer's needs and demands. This is a manufacturing philosophy. As a result of this point of view, the Navy, to a greater extent than shipbuilders and suppliers, is the subject of critique, conclusions and recommendations in the report.

The U.S. shipbuilding industry is in the midst of a fundamental transition caused by changing government policies, changing markets, and advancing technology. Changes in government policies that affect the shipbuilding and supplier industry include (1) elimination of commercial ship construction subsidies, (2) reduction in the extent of government technical responsibility for ship design and production; and (3) introduction of contract terms which permit enhanced profit in exchange for improved performance.

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[1]Limited copies of the first-phase report, <u>Productivity Improvement in U.S. Naval Shipbuilding</u>, are available from the Marine Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418.

As a result of the withdrawal of government subsidy for new vessel construction, large commercial vessels are rarely being constructed in the United States. The markets addressed by the leading U.S. shipbuilders today are those of the construction of naval combatants and auxiliaries, ship conversions, and overhaul and repair.

Following a worldwide trend, U.S. shipbuilders are advancing ship production technology, with resultant productivity improvements in terms of reductions in construction man-hours and schedules, and improvements in quality. They also are introducing computers into ship design and production, and are modernizing production management systems to bring them into conformance with modern production management requirements and methods, including the use of computers. Attention is also being paid to the quality of shipbuilder and supplier management and work to obtain the maximum productivity.

Aspects of the transition, such as advances in shipbuilding technology, are having a positive effect on the U.S. shipbuilding industry. Other aspects, such as low demand for new ship construction, are having a detrimental effect.

EFFECTS OF INADEQUATE DEMAND ON PRODUCTIVITY

It is an inescapable conclusion that insufficient sales dollars are available to sustain the U.S. shipbuilding industry with Navy work alone. The committee concludes further that government regulations and procurement policies have a substantial impact on investments made by industry and on the attractiveness of investment in the shipbuilding and supplier industry.

While the sectors of the industry which build the specialized military combatants and small craft are relatively healthy, the brunt of the inadequate demand for shipbuilding is felt in that segment of the industry which has traditionally built commercial vessels as well as large naval noncombatants and also by those naval suppliers which furnish commercial marine equipment. This is the sector of the industry where productivity has lagged the most, and where shipyards and suppliers have closed their doors.

Navy shipbuilding contracts have kept the largest possible number of these shipyards and suppliers occupied, but their workloads are far below an economic, productive level. The justification for not restricting participation in the Navy shipbuilding program in this sector to a smaller number of shipyards (similar to the acquisition policy for combatants) appears to the committee to be to safeguard the industrial base for mobilization. This, in effect, subsidizes the shipyards, without regard to efficiency or productivity. The result is to erode commitment to innovation and productivity. This is reflected by the poor showing of this sector of the U.S. shipbuilding and supplier industry in economic and productivity indicators.

The committee observes that the objectives of acquiring naval vessels in the most cost-effective manner from the most productive shipyards, and supporting an industrial base for mobilization are at cross purposes. The Navy, through its own efforts, can best focus on

the first objective. The Navy can create a business environment in naval shipbuilding that seeks to acquire ships cost effectively and promotes competition and productivity improvement. The separate issue of maintaining the industrial base for mobilization requires urgent national attention, and is not considered herein.

> Recommendation: In contracting for ships and shipbuilding supplies, the Navy should employ contracts which maximize opportunity for larger production runs, and which also contain provisions for contractors to assume greater risk in exchange for greater reward for productive performance.

The opportunity to obtain larger production runs will enable shipbuilders and suppliers to accumulate capital, modernize facilities, and improve efficiency. Contracts which enable the shipbuilder to make a profit, especially enhanced profit in exchange for improved performance, encourage management to implement the most efficient production techniques. The continuity and stability of such procurements reduce costs to the Navy, and improve delivery time and ship quality.

The effect of contracting for larger production runs would be to concentrate the Navy work in the most productive shipyards. It follows that there would then be a shake-out in the shipbuilding and supplier industry, which would add to the deterioration of the mobilization base. The erosion of industrial strength cannot continue to be ignored. The Navy can do little to save the shipbuilding and supplier industrial base by subsidizing it through its annual shipbuilding budget. Concentrating the Navy's shipbuilding work to promote economy and productivity will focus national attention on the urgent issue of the necessary size of the industrial base and its stewardship. Recommending a national strategy for safeguarding the shipbuilding and supplier industrial base is beyond the charge of the committee. However, from a technical standpoint, which is the province of the committee, the committee favors those solutions which build on advanced technology to create a more competitive and financially attractive industrial environment.

TECHNOLOGY DEVELOPMENT

The committee concludes that, while there are industry and government procedures and programs for technology development, by any measure the resources committed to them are inadequate.

The outstanding technology development activity in the industry is the National Shipbuilding Research Program (NSRP), which functions as a cost-shared, de facto technical consortium, with advice from the Ship Production Committee (SPC) of the Society of Naval Architects and Marine Engineers (SNAME). The productivity-related research and development (R&D) efforts in the shipyards and the growing awareness by management of the value of such activities are benefits which result from SPC and NSRP cooperation. As the committee pointed out in its first-year report, benefits also result from the process of technical

interaction of shipbuilders in the program. With U.S. Navy shipbuilding dominating ship construction in the United States, the task for the SPC and the Navy is to direc the SPC/NSRP to the Navy's needs to a greater extent.

> Recommendation: The Navy should continue to provide financial support to the National Shipbuilding Research Program. The Ship Production Committee of the Society of Naval Architects and Marine Engineers should address Navy needs to a greater extent under the National Shipbuilding Research Program and also offer similar advice to the Navy's Manufacturing Technology Program and other productivity improvement projects in the shipbuilding and supplier industry.

As an advisor to the Navy, the SPC would develop and maintain a folio of proposed projects; screen proposed projects for merit, validity, payback, and coordination with NSRP projects; and prioritize projects.

Two outstanding developments in shipbuilding technology, which have great potential and need to be advanced by the Navy, shipbuilders, and suppliers, are zone-oriented ship construction and the use of computers in shipbuilding.

Zone-oriented ship construction techniques are being introduced by virtually every major naval shipbuilder for constructing, converting, and overhauling naval ships, including combatants of all sizes and types. These approaches are successfully being applied in existing facilities and ship designs. Benefits accrue even on single ship efforts. Wider use of these techniques has the potential of creating substantial cost savings and schedule improvements, with concurrent improvements in quality and safety.

Zone-oriented ship construction requires earlier and more extensive engineering and planning, with supportive changes in Navy ship acquisition. Maximum utilization requires supportive developments in design documentation, ship engineering standards, and lead yard support for follow yards. Communications and contractual relationships between the Navy, its shipbuilders, and suppliers need to be improved to achieve and take advantage of reduced ship construction time.

Shipbuilders are introducing zone-oriented methods on their own initiative. These developments are in the Navy's interest. Improvements have been made, based on each yard's pursuit of its own objectives, obtaining Navy concurrence and support on a problem or project-specific basis. The Navy needs to take steps to take better advantage of the productivity improvements that these developments offer.

> Recommendation: To foster the use of zone-oriented ship construction, the Navy should: (1) develop means to apply the technology in preliminary and contract design, (2) educate its personnel on the advances being embraced by shipbuilders so that Navy practices and procedures can be adapted in support of them, and (3) work

together with its shipbuilders to provide a receptive environment for the use of productivity improving technology.[2]

The Navy creates, or contracts for, thousands of drawings and performs many more thousands of engineering calculations in designing, acquiring, and operating ships. These drawings, calculations, and specifications are provided to shipbuilders, suppliers, and the fleet in paper form. Shipbuilders and others add to the information package throughout the life of the ship.

During this process many additional drawings and thousands of calculations are completed. The same geometries are drawn and redrawn. Each time that a previously drawn geometry is redrawn or manually manipulated for any reason, or calculations have to be made based on data extracted from a drawing, there may be additional costs and errors. The opportunity exists to use a system-oriented approach for the design, specification, construction, operation, and logistical support of ships with computer-based tools and data bases that could significantly reduce costs, errors, and lead times and improve product quality.

To modernize this process, shipbuilders, suppliers, and the Navy are introducing computers in the three fundamental areas of their operations: design, manufacture, and production management. Yet, shipbuilders' systems are, in general, considerably behind the state of the art. Because the Navy is the major shipbuilding customer in the United States, it has the obligation to initiate industry-wide innovations that will lead to significant communication and productivity improvements, leaving selection and implementation of computer systems to the shipbuilders and suppliers themselves. Four areas call for Navy leadership:

- Common Engineering Data Base. A generic specification is needed for a ship product definition data base, as a basis for computerization of ship design, shipbuilding, and ship life-cycle maintenance systems.
- CAD/CAM Data Base Systems. A critical requirement not yet available in commercial data management is the ability to manage geometric information efficiently in concert with other engineering data, and at the same time provide for the production data requirement to produce on schedule the product of the required quality.
- Interactive Data Transfer. The Navy and industry need to develop the capability of using electronic data as the standard for data transfer. (While Initial Graphic Exchange Specifications (IGES) address this need in part, much remains to be accomplished.)

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[2]Specific reference is made to findings Nos. 2, 3, 6, and 8 of the committee's work group on Integration of Engineering and Production that are incorporated herein by reference (see Appendix A).

- Management Systems Development. A generic specification is needed for computerized shipbuilding industry management systems. A joint Navy- and industry-developed specification would result in reduced system implementation cost and improved ability to support ships and systems throughout their life cycle.

The committee considers advances in these areas to be high priority and critical to substantial productivity improvement in U.S. naval shipbuilding. Development efforts in each of these areas should be urgently pursued. They should involve Navy leadership, support, and technical involvement, with participation from shipbuilders, design agents, and suppliers. The leadership should consist of bringing the industry together with the Navy in a common venture, seeking the advice and participation of the industry and outside professional advisors, and sharing cost with the industry.

Recommendation: The Navy should establish a task force on computerization in concert with its shipbuilding, ship design, and supplier industry. The task force should be given the mandate and resources to complete the needed developments within the near term (1-2 years). The task force could be established by the Navy for that purpose, or the Navy could provide an existing group or groups with the charge or a portion thereof. The objective of the development effort should be to employ electronic media to a maximum extent in design, construction, management and life-cycle support in the next generation of naval ships.

The committee concludes that advances in these areas (i.e., zone-oriented construction and computerization) may converge, as they are in other industries, into flexible manufacturing systems. A shipbuilder with flexible manufacturing facilities would then be able to achieve significant production efficiencies in the building of ships, and also would be able to undertake a variety of other metal fabricating work, thus expanding the potential market. The government would be well served to encourage these technology trends and their convergence.

PRODUCTIVITY IMPROVEMENT

The naval shipbuilding industry is complex and consists of four major elements--the Navy, shipbuilders, ship designers, and suppliers--each with different goals and objectives, but each sharing responsibility for productivity improvement. Improved communication and coordination is necessary to assure a concentrated effort towards industry productivity goals. A better understanding therefore of the best management practices to effect the linking of the goals and objectives of the major players is essential. The Navy should assume the leadership role in fostering these enhancements to industry practices. The Navy needs to provide the business climate and incentives, remove impediments, and foster technology development. Industry needs to

have productivity goals, and to set objectives and achieve them. Labor and management need to work more closely to accommodate technology innovation and productivity improvement.

> Recommendation: The committee recommends that the Navy establish productivity improvement goals and incentives for its shipbuilding programs. The Navy also should require its contractors to establish and achieve productivity goals and incentives, for the mutual benefit of the contractor and the Navy. On their own initiative, shipbuilders and suppliers also should establish goals and incentives for productivity improvement.

The committee's assessment suggests five initial goals:

- o Establish finite, realistic, annual objectives, for example 5 percent/year, or real productivity improvements in terms of cost, schedule, and quality.
- o Introduce flexible manufacturing methods, with supporting organizational changes and attention to human resources.
- o Apply zone-oriented shipbuilding on first-of-a-class or prototype designs and in naval ship conversion and overhaul, in addition to follow-ship new construction.
- o Develop a better understanding of shipbuilder/supplier relationships and encourage the development of industry-wide management practices to better link the goals and objectives of shipbuilders and suppliers.
- o Develop common engineering data bases as well as systems to enable automated transfer of data among Navy organizations and among the Navy, its shipbuilders, design agents, and suppliers, throughout the life of a ship.

These five goals apply at least in part to every element of the industry. In setting goals, the committee wishes to emphasize that measuring improvement is less important than building a process of improvement into an organization. Achieving these or similar goals will necessitate the total commitment to productivity improvement of the Navy, its shipbuilders, and suppliers.

In support of the goals, the Navy, shipbuilders and suppliers should jointly develop plans for 5 years or longer to modernize ship design, shipbuilding technology, and management systems. It is recognized that each shipbuilder's overall modernization plans are proprietary, but, transfer and control of data between the Navy, design agents, shipbuilders, and suppliers should weave a thread throughout all the plans. The shipbuilders' plans must be compatible with future Navy methods of communicating and managing data. At the same time, the Navy needs to take advantage of the advancing technology in the use of electronic data instead of the more conventional documentation.

It is evident that, between the Navy and its shipbuilders and suppliers, a balance of views and interactions is achieved in several areas such as ship system engineering, accounting, and contracting.

It is not evident that there is any comparable shared interest and involvement in the area of productivity enhancement. Furthermore, the Navy does not help itself or the industry by taking the attitude that productivity improvement is a shipbuilder and supplier problem.

Without a focus for productivity improvement, important productivity initiatives languish. Each shipbuilder and each Naval Sea Systems Command acquisition manager is left to go it alone. The Navy needs to take the long-term view of its productivity interests.

> Recommendation: The Navy should establish a focus for productivity improvement within its organization.

One possibility is the creation of an advocacy program to push for productivity improvement in naval shipbuilding. An analogy might be made to the office of competition established within the Navy. A productivity office would: administer U.S. Department of Defense (DOD) and Navy productivity improvement programs (including establishing goals with industry;, work with Navy offices to structure acquisition programs for promoting productivity improvement; assist Navy contractors in obtaining Navy support, concurrence, or participation in contractor-initiated productivity improvements (an example might be early release of contractual holdbacks for the purpose of capital improvement); and stimulate, coordinate, and undertake productivity improvement projects as called upon and appropriate.

A longer-term and possibly more comprehensive step would be to establish a productivity improvement chain of command within the Navy to serve a function analogous to that of the R&D chain of command, that is, to monitor, oversee, plan, and direct private and public sector productivity improvement efforts in support of overall Navy missions. This would build into Navy personnel practices the opportunity for professional recognition for achievements in productivity improvement. In conjunction with this, the Navy should consider earmarking a percentage of acquisition program dollars for productivity improvement programs, in a manner similar to that employed in R&D administration.

The committee offers several additional specific comments concerning existing productivity improvement and related issues.

- Manufacturing Technology Program. In addition to cementing an advisory relationship with the SPC, the funding and contracting cycle of the program needs to be revamped with the objective of shortening the 3- to 5-year delay between proposing and funding a project. This time lag has a marked effect on the relevance of the program, and participation in it.
- Industrial Modernization and Incentives Program. This program has been used more in the manufacturing than in the shipyard environment. Presently, its most appropriate role in shipbuilding is in combat systems. With the advent of productivity improvement goal-setting in the industry and the Navy's focus on productivity, there may be more opportunities for its utilization in shipbuilding.

- <u>Management System for Notifying of Changes in Technical Documentation</u>. The citing of different editions of the same specification in different shipbuilding contracts (sometimes for the same shipbuilding program) is a particular problem to suppliers and shipbuilders. A system needs to be developed to simplify and speed the communication and implementation of changes, and the authority to use them. The system also should be capable of accommodating the shipbuilder's or supplier's occasional need to use a different version of a specification than the one cited in the contract without extensive administrative procedures, as in change proposals. It is appropriate to assemble a joint government and industry task force to devise the needed management system.
- <u>Supplier's Rights in Data</u>. Past and present applications and loose interpretation of rules affecting rights in data are viewed as a serious problem by suppliers who feel their privately funded investments and technology development efforts are being systematically eroded. Regardless of which rights-in-data rules apply in the future, the supplier's legitimate rights in data, however broad or limited, must be respected if the Navy expects to have an effective and responsive supplier base.
- <u>Standards</u>. U.S. shipbuilding continues to suffer from an inadequate standards development and application effort. The infrastructure for design, hardware, and information systems standards is in place, but adequate resources have not yet been dedicated by shipbuilders or the Navy. The Navy should convert military specifications to commercial standards wherever appropriate, and also accelerate and increase its military specifications (MilSpec) improvement program.
- The Navy should actively support national, generic approaches to aid all industries; these measures will also aid shipbuilders and suppliers. To encourage productivity-enhancing capital investment, the Navy could ask Congress to enable shipbuilders and suppliers to save earnings on a tax-deferred basis, so long as they are used for capital improvements. The committee has not fully evaluated this idea, but envisions a mechanism similar to the Capital Construction Fund in merchant shipping.

The committee, in its report, has identified a multitude of other productivity-enhancing innovations. The degree to which they are understood and adopted by the Navy and the industry in the near-term, and applied and implemented in the mid- to long-term, will depend on the amount of communication and education on and about them. For this reason, the Navy, its shipbuilders and suppliers, including management and labor, need to cultivate every opportunity for information sharing, communication, and education. The committee fully recognizes that the Navy has made advances in this direction in the past several years. However, it is believed that still more can be done to the mutual advantage of the Navy, its shipbuilders and suppliers, their labor forces, and, in the end, the taxpayer. Advances do not depend on the work of one advisory group, but on the development, in a cooperative business environment, of mutual understanding on the common problems of business and technology.

SHIPBUILDING IN THE UNITED STATES

INTRODUCTION

During World War II, the U.S. shipbuilding industry produced over 5,700 merchant ships and over 1,500 naval ships. At the war's end, the numbers of naval and merchant ships exceeded peacetime needs. As a result, the U.S. shipbuilding industry, including its supplier base, contracted significantly to a size sufficient for replacement production. This level of U.S. ship production, measured in tonnage, was stable for many years, in spite of periodic episodes of shipbuilding elsewhere, with growth in the worldwide industry occurring mainly in the Far East. Since World War II, the United States has remained a relatively minor force in world commercial shipbuilding, producing less than 3 percent of world tonnage.[1] However, the U.S. shipbuilding and repair industry is the largest naval shipbuilding industry in the non-communist world, and, measured by dollar volume and labor force, is among the three largest in the world.

The tonnage of Navy orders for new construction has remained relatively constant, except during the Vietnam conflict. However, tonnage alone does not present a complete picture of the shipbuilder and supplier business environment for several reasons. Tonnage is not an adequate measure of volume of work for combatant shipbuilders because of the complex electronic, combat, and other systems on

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[1]Far Eastern countries advanced their shipbuilding industries in this period by capitalizing on lower labor rates and government support as well as placing emphasis on development of modern production methods and facilities. Starting in 1951 with pre-war facilities and mass production methods used by the U.S. in the war, Japan captured 22 percent of the world's orders and passed Great Britain in 1956. Using the same pre-war facilities, but continuing to advance their production methods, Japan obtained 40 percent of the world's merchant shipbuilding orders by 1964. Only at that time were new facilities constructed to accommodate the larger ships (i.e., supertankers) that were then being designed, and not to relieve production bottlenecks in the older facilities.

combatant vessels (for example, an 18,000-ton Trident submarine has far greater capital, material, and labor requirements than an 18,000-ton auxiliary or merchant vessel of any type). Furthermore, industry-wide tonnage data mask the peaks and valleys of activity that have been encountered by every shipbuilder as shipbuilding programs have been sucessfully launched or cancelled, and contracts won or lost.

Regardless of the fortunes of individual companies, Navy orders plus the diminished demand for merchant ships have been inadequate to utilize the total capacity of the nation's shipbuilders. Furthermore, the segment of the shipbuilding industry which has actively sought Navy construction orders has, on occasion, planned for building programs which never materialized. To cite just one example, in the 1960s the Navy placed under contract five private yards and two public yards to build nuclear ships. This was done at substantial expense. Yet, a large portion of the program, the nuclear surface ships, never came to fruition. As a result, the two public yards were removed from the nuclear shipbuilding program, one of the private yards went out of business, and another was sold and thereafter built no nuclear ships.

Estimates of future production often have not been translated into orders. At times, orders have been influenced by concern for the industrial base. The resulting erratic and uncertain flow of orders for any one shipbuilder has negatively affected the supply and turnover of skilled craftspersons.

STATUS OF THE U.S. NAVAL SHIPBUILDING INDUSTRY

Overview of Shipbuilders

The shipbuilding and repair industry includes 605 establishments, but, only about 300 companies have 20 employees or more. Four companies, all naval shipbuilders, account for 43 percent of industry shipments (which totalled $9.8 billion in 1983) and 48 percent of the labor force (which totalled 145,000 in 1983).

The naval shipbuilding industry is composed of private and public sectors. The public sector includes eight government-owned shipyards that concentrate on overhauling and repairing Navy combat ships. The private sector is composed of those privately owned shipyards, currently 24 in number, engaged in or actively seeking naval construction and conversion contracts.

Shipbuilding is a labor intensive industry. For comparison, the ratio of employees to value added in the shipbuilding and repair industry in 1980 was 1.5 times that in the motor vehicles industry, and comparable to that in the heavy construction industry.

From 1972 to 1983, the compound annual rate of growth of the industry was 1.7 percent. At the same time, total U.S. manufacturing grew 30.3 percent. (The leading industry during this period. electronic components, grew 128.7 percent.) These statistics demonstrate that the shipbuilding sector is among the lowest growing of U.S. industries in terms of real production. There are industries that actually lost ground, such as steel mill products, iron and steel

foundries, leather, and cotton fabrics. While shipbuilding is not in the negative category, its growth is very low, and measures to improve the competitiveness of U.S. industries overall are likely to leave shipbuilding still in a very unfavorable posture.

The private sector of the industry is unable to compete on equal terms for commercial ship orders in world markets. Leading commercial shipbuilding countries foster commercial construction and repair with substantial direct and indirect subsidies. Thus despite the best efforts of U.S. shipbuilders to improve their productivity, hopes for revival of commercial U.S. shipbuilding are not likely to be realized in the near future. Therefore, presently and for some time to come, the primary markets are those of naval ship construction and conversion, naval ship overhauls, limited privately financed construction, and repair work, both naval and commercial. (It is also technically feasible for shipbuilders to enter totally new markets, in competition with other fabricators.)

From the standpoint of naval ship construction, conversion and overhaul, the industry can be structured into four classes: nuclear combatant, non-nuclear combatant, noncombatant, and coastal vessels (see Table 1).[2]

Table 2 summarizes the Navy's five-year plan for construction and conversion of ships during the period of fiscal years 1984 through 1988.

In the context of the four classes of shipbuilders shown in Table 1, it can be seen that during the five-year period, 23 ships funded for $34 billion are targeted for the two nuclear-qualified shipyards. A similar number of ships and amount of funding describe the market for those yards that will compete for non-nuclear combatant orders. Although $24 billion is the size of the market for the eight to ten shipyards that will likely bid for the noncombatant ship programs, the average number of opportunities per year per probable competitor is about the same as in the other two market segments.

History has shown that the Navy's nuclear and non-nuclear combatant acquisition plans tend to be more stable than noncombatant ship plans. Also, the noncombatant segment in the current five-year plan reflects the special activity of the strategic sealift program. Therefore, future plans may include relatively fewer noncombatant ships.

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[2]The structure of the repair industry is more complicated. It involves geographical and facility features and types of work considerations as well as ownership differences. This subject is discussed in the committee's working paper on capital formation.

TABLE 1 Naval Shipbuilders[a]

	Combatant			
	Nuclear	Non-Nuclear	Noncombatant	Coastal
GD-Electric Boat	o			
Newport News	o			
Bath Iron Works		o		
Ingalls		o		
Todd		o		
American			o	
Avondale			o	
Beth-Sparrows Point			o	
GD-Quincy			o	
Lockheed			o	
NASSCO			o	
Penn Ship			o	
Tacoma			o	
Bell Halter				o
Derektor				o
Marinette				o
Peterson				o

[a]Shipyard's order book includes these programs within the last 18 months.

TABLE 2 Navy New Construction Five-Year Plan

	Combatant				
	Nuclear	Non-Nuclear	Noncombatant	Coastal	Total
No. of Ships	29	27	88	a	144
Cost (billion)	34	30	24	.8	88.8
Percent of Total	38	34	27	1	100
No. of Shipyards	2	3	8	4	17

[a]Not quantified because of large numbers of small craft.

Overview of Shipbuilding Suppliers

The shipbuilding industry includes the shipbuilder as well as all suppliers of combat and electronics systems, and all other machinery and equipment to the completed ship. The shipbuilding industry is very dependent on its suppliers because shipyards are not integrated production facilities. Ships are produced by fabricating and assembling materials from a variety of suppliers, from steel mills and foundries to manufacturers of highly sophisticated propolusion machinery, and from assemblers of high-technology electronics and combat systems to suppliers of the thousands of fasteners, fittings, gauges, and other items that go into making a modern naval ship.

As much as two-thirds of the cost of a major naval combatant ship acquisition is value added by suppliers, with the remainder the value added by the shipbuilder (U.S. Congress, 1984). When applied to the Navy's five-year plan shown in Table 2, $29.6 billion of the $88.8 billion program is therefore the value added by the shipbuilders. A productivity improvement of, for example, 10 percent, by shipbuilders could save $2.96 billion in the five-year program. Consider as well achieving the same hypothetical 10 percent savings in the suppliers' two-thirds of the program. This could be $5.92 billon, twice the savings potential in shipbuilding for the same productivity gain.

Suppliers furnish materials and components for ships as either part of the original construction, or as the inventory of spare parts to be used in current or future overhaul or repair. They can range from suppliers of standard, off-the-shelf items to firms providing highly sophisticated and classified weapons or electronics systems. Sold directly to the shipyard, supplied items are referred to as "Contractor Furnished Equipment" (CFE). When the government buys directly from the supplier and then furnishes the item to the shipyard, the material is referred to as "Government Furnished Equipment" (GFE). The diverse roles of suppliers are depicted in Figure 1, which illustrates that the Naval Sea Systems Command (NAVSEA), the primary acquisition manager for Navy ships, engages contractors for the detailed design and construction of ships as well as companies to manufacture long lead-time items. Other contracts, such as for combat systems and electronics, also are awarded by the Navy. The figure illustrates that the shipbuilders engage material, equipment, systems, and services suppliers. Multiple shipbuilders engage common suppliers.

Suppliers are important to the Navy's shipbuilding program. Within the five-year acquisition plan for naval vessels, shipbuilding dollars will be distributed about equally among contractor-furnished equipment, government-furnished equipment, and shipyard labor cost. The shipyard is paid for hull fabrication, system assembly and test, and overall ship production. The remainder of the cost of building the vessel is devoted to materials and components furnished by suppliers.

There are about 5,000 naval shipbuilding suppliers. The supplier industrial base can be better understood through a survey of 543 companies who provide contractor-furnished or government-furnished equipment to shipbuilders (NAVSHIPSO, 1981). This survey classified suppliers by the type of goods furnished: basic materials,

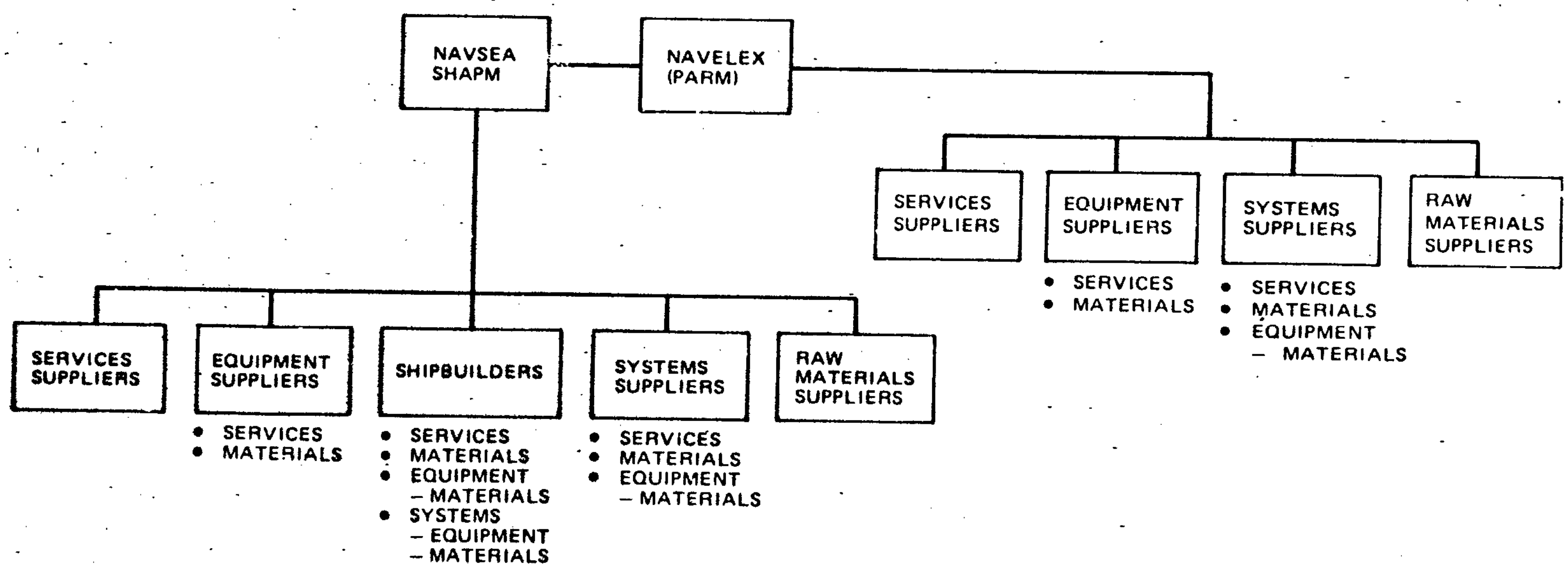

FIGURE 1 Flow-down model of the shipbuilding industry.

semi-finished products, or finished components. Over the wide range of firms represented, each class of suppliers utilized their facility from two-thirds to three-fourths capacity. Further, companies surveyed expressed a number of common problems, including the lack of profit on Navy orders, a shortage of skilled labor, and very long lead times for some materials and equipment. In some instances producers of semi-finished goods were frustrated by the wait for basic materials, and the producers of finished components were constrained by the long lead times of semi-finished goods and sub-assemblies.

A number of suppliers also stated that they planned to diversify and expand capacity. However, planned expansions would be used to produce mostly non-Navy work. This would further reduce the percentage of sales derived from Navy orders.

In spite of plans to expand capacity, the survey concluded that the industrial base is shrinking, but is adequate for current programs.

The committee compiled a case study of the noise quiet bearing industry which provides insight into the effect of U.S. Navy actions on shipbuilding suppliers (Appendix B). The case study showed that U.S. manufacturers withdrew from the Navy quiet bearing market over a 15-year period. The reasons for the withdrawal are two-fold: (1) the increasing unattractiveness of the Navy market as the result of ever-tightening technical requirements and low-volume unprofitable orders, and (2) stiff foreign competition. In the market conditions that prevailed, the U.S. manufacturers of quiet bearings for military applications simply could not keep up with the foreign supplier on the basis of cost, delivery time, and quality. The case study does not imply that all sources of supply are going to end up foreign. It does, however, exemplify the pressures being brought to bear on suppliers.

Supplied items are especially critical for shipbuilding if they are used extensively (i.e., installed on most ships), if their manufacturing lead time is in excess of 18 months, if their production is characterized by low volume or unique production processes, or if the item is critical to the ship construction schedule. Another factor is the lack of a sufficient number of domestic suppliers to ensure competition.[3]

A related consideration, from the standpoint of national security, is the extent to which the lead times of supplied items such as combat and electronics systems and other long-lead time items control the capability to expand shipbuilding capacity. In a wartime expansion of shipbuilding capacity, naval shipbuilders would accelerate the construction of ships on order by adding shifts (up to a total of 21 per week as opposed to the peacetime norm of 5+). A build-up in the

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[3]A list of critical items is contained in Appendix B of the Report of the Work Group on Shipbuilding Suppliers. Limited copies are available from the Marine Board, National Research Council, 2101 Constitution Avenue N.W., Washington, DC 20418.

supplier industry, started at the same time, would not result in long-lead items to support new construction for some 12-18 months. By that time, the shipbuilders, having accelerated the construction of ships on order, would be ready to undertake new construction. The point is that the schedule for the production of long-lead time items is less flexible than the schedule for ship construction.

Forecast

An economic forecast for the shipbuilding industry was recently prepared for a consortium of shipbuilders (Kasputys, 1984). The forecast projects that, without national programs to stimulate commercial shipbuilding, defense-related shipbuilding and repair work will grow 7.3 percent annually from 1983 to 1989. However, non-defense shipbuilding and repair will decline at an annual rate of 16 percent reflecting both market conditions and the noncompetitive position of the U.S. shipbuilding industry. The weighted results of these two trends is that the total level of activity only grows by an annual average of 1.6 percent. One can infer from the forecast that the shipyards that have relied on the construction of merchant vessels for their work load in the past will be faced with continued declining or low demand, while those that are qualified to build combatants face somewhat brighter prospects.

Investment and Profitability

Private Shipbuilders

A review of the U.S. shipbuilding industry's profitability covering the period 1947 to 1976 revealed two major findings (Kaitz, 1978): that the industry is two-tiered, with one group of profitable companies and another group that has sustained losses. Since 1976, the industry has remained two-tiered, and the gap between the winners and losers is widening.

Aside from the few bright spots provided by the naval expansion program, virtually every indicator of the financial health of the industry has continued to deteriorate. Since 1978, the value of work completed has dropped 8 percent, total employment is down 9 percent, and the number of production workers dropped 17 percent in just 1 year, between 1981 and 1982. Nevertheless, from 1980 to 1984, the U.S. shipbuilding industry spent \$1.32 billion on capital improvements. Table 3 shows that this represents 1 to 3 percent of annual revenue (about 80 percent of which derives from the Navy). However, the most profitable shipyards direct a considerably greater percentage of revenue to capital investment.

TABLE 3 Capital Investment in the Shipbuilding Industry ($ million)

Year	Capital Investment[a]	Value of Work Completed[b]	Navy Order Book[c]
1980	$263	8,889	9,100
1981	190	10,690	9,900
1982	329	10,293	10,400
1983	322	9,107	16,000
1984	218 (est.)	8,308	20,063

[a]Data collected by Maritime Administration, based on voluntary reporting of shipbuilders. Estimated to be 80-90 percent complete.

[b]Data collected by Census Bureau on S.I.C. Code 3731. Reported as "value of shipments" in Census of Manufacturers and Annual Survey of Manufacturers. Years 1982-1984 are estimates based on census data, reported in U.S. Industrial Outlook 1984.

[c]Data obtained from Shipbuilder's Council of America, based on analysis of federal procurement spending performed by CACI Corp.

Most of the improvements have been directed at facilities maintenance and modernization, and expanding shipyard capacity to construct or repair larger ships. More recently, shipbuilders have invested in changes in process control and material handling so that they can take advantage of group technology. Investments have also been made in CAD/CAM technology and in administrative and infrastructure improvements. In 1982, six major shipbuilders completed self-assessments of their technology needs at the request of the Navy. Areas of special interest identified in the surveys were facilities modernization and applications of newer, available technologies.

The majority of the capital investment has been spent by a handful of shipyards as a consequence of or in anticipation of Navy work. Out of an industry total of $329 million in capital expenditures in 1982, $144 million was spent by just two shipbuilding companies.

While some shipyards used capital improvement funds to implement new technologies, such as CAD/CAM, the period between 1976 to 1980 saw a widening of the merchant shipbuilding technology gap between European and foreign shipyards, and U.S. shipyards (Marine Equipment Leasing, 1979). Since then, in part due to enhanced profit incentives in Navy contracts, shipbuilders have started to narrow the technology gap and

in many instances are leading in complex naval combatant shipbuilding technology (see subsequent chapters of this report).

Shipbuilding Suppliers

The shipbuilding market has not proven to be attractive for a number of suppliers of raw materials, semi-finished goods, and finished components, on account of inadequate and erratic demand. Further, it is anticipated that the merchant shipbuilding market will no longer be a significant factor in U.S. shipbuilding. These conditions of static or declining market opportunity, which are likely to prevail for a long time, make the shipbuilding market unattractive to the supplier. Consider Figure 2, which illustrates the relationship between market share and market growth.

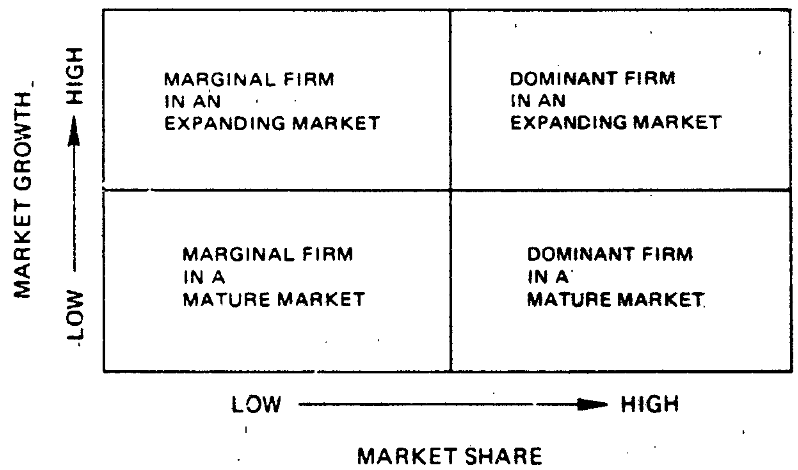

FIGURE 2 Market attractiveness.

The most desirable operating position is that of a high market growth and a high market share. An example of this in shipbuilding might be "sole source" electronic weapons systems. Major awards are sought by many firms because the research, development, and manufacturing expertise gained by developing and producing these systems is transferable to many other systems. Electronics and weapons also often are procured on a sole source basis.

Sometimes, in weapons system acquisition, competition is rejected because of the high cost of developing another source or for security reasons. In these cases, the relationship between the government, which purchases and provides the equipment (i.e., GFE), and the supplier, is usually sound and supportive. Yet, as will be illustrated later, the same type of relationship is often missing for commercially available CFE.

Outside of combat and electronics systems, the naval shipbuilding supplier markets can best be described as low growth. A low-growth market can be tolerated if there is a reliable stream of orders, and if the firm has a dominant market share. This allows the firm to quote prices, which produce adequate profits. This market can be a reliable source of profits under the right situation. The sector could emcompass many GFE items such as traditional weapons systems. A single supplier is chosen to develop and produce the item at an agreed upon cost. Consequently, while the volume may be low, the market share and the profit are both sufficient for the supplier to stay in the business. This is the sector of the matrix that all low-volume producers should seek to remain in business.

The low-growth, low-market share sector of this matrix is the worst position for a company. Because of the low-market share, there is no way that the supplier can obtain prices that cover cost plus profit. Selling prices are controlled by the lowest price that a producer with excessive capacity wishes to set. Marginal producers try to maintain cash flow and fill some of their unused plant capacity by only covering their variable costs. This allows no return on invested capital, and will eventually drive the producer out of the market. Further, there is no growth potential to allow producers to work their way toward recovery.

The pattern described for the low-growth, low-market share case is a classic example of economic forces working properly in the market place. The lack of reliable, long-term shipbuilding orders from the Navy has resulted in low-growth market conditions. Suppliers of CFE with numerous competitors will do poorly. This is especially true where Navy material specifications differentiate the product from a commercial standard so that it cannot be an "off-the-shelf item" with a potential to gain market share through commercial sales. Firms will continue to drop from these markets until one of the remaining firms gains sufficient market share to set prices that cover cost plus profit. Alternatively, as shown in Appendix B, competitive forces can favor lower-cost foreign suppliers over U.S. suppliers.

Productivity

Table 4 shows the changes from 1970 to 1980 in the value added per employee in the shipbuilding and repair industry, and two other industries for comparison. The table shows that while the automobile industry has more than doubled its productivity in the decade, shipbuilders have improved their productivity about 35 percent. This is somewhat greater than improvement achieved in the steel industry. Further, it shows that the shipbuilding industry in 1980 contributed only 57 percent of the value added per employee when compared to the steel and automotive industies. Value added is a total factor measure of productivity, including labor, capital, material, and energy inputs. A measure of labor productivity only is the value of work completed per man-year. This measure of shipbuilding productivity (in constant dollars) held nearly stagnant at $27.000 per man year from 1979 to 1984.

TABLE 4 Value Added Per Production Worker Per Hour[a]

Industry	Value Added Per Production Worker Per Hour 1970	1980	Percent Improvement
Automotive	15.40	32.33	110
Steel	29.40	32.66	11
Shipbuilding	14.00	18.99	35

[a]Adjusted to normalized dollars.

SOURCE: Bureau of the Census.

U.S. shipbuilding productivity in the construction of commercial vessels in comparison to foreign productivity has been studied, with the conclusion that productivity in the best foreign shipyards is on the order of 100 percent better than in major U.S. shipyards (Marine Equipment Leasing, 1979; A & P Appledore Ltd., 1980). The referenced studies have emphasized hull construction over the other elements of shipbuilding. Moreover, the committee is not aware of any comprehensive industrial engineering and cost driver analysis suitable for steering improvement efforts.

Much of the difference in productivity in construction of commercial vessels can be accounted for by differences in wages, currency exchange rates, political pricing, and economies of scale. With these barriers to becoming competitive, issues of production technology become secondary.

U.S. productivity in naval ship construction is another matter. While there are no publicly available comparisons of productivity in naval ship construction comparable to those on commercial construction, the committee found sufficient data in its first year to conclude that the very significant time and cost differences which are so widely advertised in U.S. and foreign merchant shipbuilding comparisons may not be the case in U.S. versus foreign naval shipbuilding (National Research Council, 1982). The lack of volume, the great complexity, and the higher technology implicit in naval shipbuilding appear not to put foreign shipbuilders in the superior position they enjoy in merchant ship construction. However, there are indications of increased construction of naval vessels worldwide (U.S. Naval Institute, 1984), and as foreign shipbuilders gain experience in naval construction it is likely that they will become increasingly competitive.

Furthermore, since the referenced studies on the productivity of U.S. shipbuilders were completed in the late 1970s, every major naval shipbuilder has made significant strides to improve productivity.

There has been capital investment to modernize facilities, technical investment to modernize ship production processes, and human investment to motivate the work force towards productivity. The Navy has introduced incentivized contracts, encouraged competition, and improved government-industry working relationships. These developments are documented in the committee's technical assessments.[4]

The productivity improvement measures being implemented in forward-planning U.S. shipyards should significantly reduce ship construction labor and materially reduce overhaul and ship repair labor input. Isolated productivity improvements already have halved the labor content of certain phases of ship construction.

Mindful of the value added by shipbuilding suppliers to U.S. naval shipbuilding, the committee sought information on their productivity.[5] In particular, it sought to determine the extent to which: products are being designed for production, computer-generated data bases are in use in design and production, and the engineering and production phases of manufacturing are being integrated. The suppliers consider attention to productivity improvement to be synonymous with sound business and management practices.

A manufacturer of defense electronics systems explained to the committee that its efforts to improve productivity and reduce costs are in four areas--personnel policies, the use of computers, plant improvements through capital investment, and research and development (R&D). For this manufacturer, R&D has resulted in smaller, more capable computers, robotic applications for manufacturing, very large-scale integrated circuitry and its smaller size and multiple functions, and general automation procedures which have been implemented. Computer use has increased exponentially in recent years in the areas of computer-aided design, simulation of system performance, word processing, data storage and retrieval, component testing, and mail distribution. Computers also enable more data analysis, assist in cost control of programs and provide useful data, properly formatted, to eliminate costly areas in the manufacturing process. Capital investment has been made to improve facilities and to implement new capabilities. Finally, in the area of personnel practices and procedures this manufacturer stresses training, and also low personnel turnover.

As a result of attention in these areas, this manufacturer has been able to sustain 20 percent growth per year over 5 years. At the same time, it has made deliveries on a major program ahead of schedule (on an already accelerated schedule) for over 3 years, while also reducing the unit cost of the product in the same period.

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[4]The technical assessments are contained in the committee's first-year report (National Research Council, 1982), and in the working papers of the second year, whose findings are presented in Appendix A.

[5]This section is based on presentations to the committee by Richard Glenn of Jered-Brown Brothers, Inc., and Eugene Avallone of Gould, Inc. Limited copies of these presentations are available from the Marine Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418.

The manufacturer credits its production performance to its attention to productivity improvement, and cites the Navy's long-term contract for a multi-year production effort as an important precondition for each of the corporate initiatives. Thus, the attitudes and actions of the Navy as customer are as important to supplier productivity as are those of suppliers.[6]

STATUS OF GOVERNMENT PROGRAMS TO IMPROVE SHIPBUILDING PRODUCTIVITY

A number of government programs promote progress in shipbuilding productivity. These include: established programs, with their own budgets and project selection procedures, that conduct R&D or otherwise advance the state of the art; naval acquisition programs, which provide the motivation for productivity improvement; congressionally mandated studies; and other study programs. At the time of this committee's study, there were at least 11 current studies of shipbuilding.[7] Appendix C comments on the status of programs in the first category--those that conduct R&D or otherwise advance the state of the art of shipbuilding technology.

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[6]This subject is addressed at length in subsequent chapters.

[7]Assessment of the Shipyard Mobilization Base, by the U.S. Navy; An Assessment of Maritime Trade and Technology, U.S. Congress Office of Technology Assessment; Assessment of Maritime R&D, U.S. Congress Office of Technology Assessment; Building a 600-Ship Navy: Cost, Timing, and Alternative Approaches, U.S. Congress, Congressional Budget Office; U.S. Shipping and Shipbuilding, Trends and Policy Choices, U.S. Congress, Congressional Budget Office; Marine Transportation in the United States: Constraints and Opportunities, National Advisory Commission on Oceans and Atmospheres; Status of Shipbuilding in the United States, National Advisory Commission on Oceans and Atmospheres; Status of U.S. Maritime Mobilization Base, Georgetown Center for Strategic and International Studies; Committee on U.S. Shipbuilding Technology, National Research Council of the National Academy of Sciences; Blue Ribbon Panel of the Ship Production Committee of the Society of Naval Architects and Marine Engineers; International Trade Commission study of the competitive condition of the U.S. commercial shipbuilding and repair industry.

3

INVESTMENT, PROFITABILITY, NAVAL SHIP ACQUISITION, AND PRODUCTIVITY

THE IMPORTANCE OF CAPITAL FORMATION TO THE NATIONAL DEFENSE

An understanding of the interdependence of capital formation and sales income is central to an analysis of the problems facing the U.S. shipbuilding industry. For more than 20 years, the industry's sales base has been inadequate to support its structure (Kaitz, 1978). An adequate sales base has been the key ingredient missing from the capital formation process in the industry. There are simply insufficient sales dollars available to sustain the U.S. shipbuilding industry as it is now organized. Furthermore, it is unlikely that the sales dollars needed to perpetuate this status quo will ever be available again.

The national strategy for the shipbuilding industry has been to preserve a defense base by generating sufficient sales income to maintain the status quo in the shipbuilding and supplier industry by having the taxpayer subsidize both the shipbuilding and sea transport industries. The strategy has maintained the facilities in the industrial base, but with few exceptions it has not been structured to force the competitive modernization of the industry. As a result, the U.S. shipbuilding industry is not competitive in the international commercial market and will most likely remain that way. Whatever commercial demand for U.S. shipbuilding has been felt in the past 20 years has been created by taxpayers' dollars.

Before national commitments can be made to modernize the U.S. shipbuilding industry, it will be necessary to make decisions concerning the size and shape of the industry needed. Two scenarios illustrate the range of national choice:

- The first scenario would limit the national interest to those shipyards that (a) have a proven ability to compete effectively for naval construction and those (b) able to compete effectively for their share of an unsubsidized protected commercial market. The national interest would be defined by the Navy's shipbuilding program, which runs at about 20-25 large ships per year and provides jobs in new construction for about 100,000 shipyard workers. This scenario would target as many as six large private shipyards (those vital to the Navy's interest) for modernization. The rest of the industry would have to take care of itself.

- The second scenario would maintain the status quo considered capable of constructing either complex naval combatants or large commercial vessels. This number is exclusive of the approximately 300 smaller ship, boat-building, and repair yards that in some instances are able to generate their own unsubsidized sales income.

The lack of consensus on the appropriate size of the U.S. shipbuilding industry results from its being a "defense industry." In time of war, the demand for its products will grow substantially as will the priorities set for these products. Therefore, the tendency is to protect the status quo, which is the residue of an industry that produced over 5,700 commercial and 1,500 major combatant ships during World War II.

Equating the mobilization base with the status quo leads to specious reasoning, which begins with the statement that the sales base is inadequate to provide the profits needed to promote a technologically sophisticated industry. This lack of sophistication then means that the industry cannot become price competitive and, in turn, is subsequently unable to generate the sales required to buy the technology that it needs. Moreover, the initial lack of technological sophistication fosters a situation in which even those firms that compete successfully do so by being less efficient than they would otherwise be. The strategic problem here is self-evident. Even if market forces are allowed their full effect and otherwise noncompetitive firms drop by the wayside, the surviving members of the industry may be economically viable domestically despite the fact that they remain technologically deficient.

Concentrating the full effects of the demand side of the capital formation process into a limited number of shipbuilders and suppliers makes profound economic sense provided that these yards generate their own supply side funding in adequate amounts to upgrade their technological capabilities. Allowing them to retain their own version of the competitive status quo would be improper and inappropriate as is, parenthetically, the status quo in an otherwise free, market-oriented economy.

Fortunately, the evidence is that the winning companies are willing and able to invest adequate sums of monies in the new technologies. Moreover, they have substantial surge capacity (Lowry and Hoffman, Assoc., Inc., 1980). If a commitment to a free market, highly competitive economy is to be maintained, diverting funds to other less efficient companies is, from a purely economic standpoint, inappropriate.

The most efficient national strategy for ensuring that U.S. shipbuilders and suppliers can support the U.S. defense effort with modern, productive facilities would appear to be to allow competition as the driving force behind the size of the industry, and to enable competitive shipbuilders and suppliers to accumulate sufficient capital to upgrade their technological capability. It should be recognized that this strategy will not provide for potential surge requirements for national defense. These surge requirements once identified would have to be separately structured and funded.

IS CAPITAL FORMATION A PROBLEM IN THE SHIPBUILDING INDUSTRY?

To adjudge whether there is a capital formation problem in the shipbuilding and supplier industries, it is necessary to determine whether the industry has had sufficient capital. Has the industry invested its funds in productivity-enhancing measures? Will the near future provide adequate markets so as to provide profits and cash flow for investment? If adequate investment has taken place, has it been spent wisely and executed effectively?

Answering the questions definitively would require facts and figures and analysis, which were not available to the committee.[1] Without the data to definitively resolve the capital formation issue, the committee sought insight into the capital improvement planning, budgeting, and decision-making processes of U.S. shipbuilders, as well as the involvement of the Navy and investors in capital improvement decision making and capital formation, by means of case studies of recent capital improvements in the U.S. naval shipbuilding industry (Appendix D).

Without definitive data, the case studies and other materials (Kaitz, 1978, and annual reports of the Department of Defense Coordinator of Shipbuilding, Conversion, and Repair, and the Shipbuilders' Council of America) provide substantial evidence if not proof that there has been some profit and increasing productivity, and that the gains are concentrated in the few shipyards and businesses that have captured the lion's share of the U.S. Navy's orders. Not coincidentally, these are the companies that have been bold, aggressive, and invested wisely, and managed with verve and discipline. The case studies indicate that investment, technology, and productivity are creating strategic advantage in the shipbuilding industry. If so, then capital formation is not the problem. The problem is the lack of demand for shipyard and supplier products. Being witnessed in the shipbuilding industry is a difficult but economically rational shakeout caused by insufficient demand for ships and the failure of affected managements to compensate.

THE PROBLEM OF INSUFFICIENT DEMAND FOR SHIPS

The primary constraint on capital formation in the shipbuilding industry is the uncertain and low demand for shipbuilders' (and suppliers') products. As a result of uncertain and low demand, any increase in productivity resulting from the introduction of new technologies is likely to be offset by the production inefficiencies that result from underutilization of available capacity. To quote from a recent congressional report:

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[1]The most relevant data set known to the committee was compiled for the U.S. Navy using data through 1976 (Kaitz, 1978).

> Volume is the prime factor in a highly productive shipbuilding industry. Without large numbers of ships to build, it is not possible to hone the productive process to a sufficient degree to reduce costs. (OTA, 1983)

This is not to say that it is futile to seek out new technologies and to explore the financing mechanisms needed to put them into place. It is, however, important to recognize that machinery or labor, no matter how innovative, has no productive value if it remains idle or underemployed due to lack of demand. The shipbuilding industries of some other countries have responded to reduced demand for ships by rationalizing their capacity and improving their management of production. Since 1977, for example, shipbuilders and suppliers in Great Britain have reduced their work force by 28 percent, closed two engine manufacturers, and 10 new construction shipyards. The Japanese and other countries are also reducing their shipbuilding capacity.

Although a more detailed picture of the status of the industry has been provided elsewhere, the following observations relating to the problem of insufficient demand are relevant here:

- The slump in commercial shipbuilding orders is not a U.S. phenomenon. Until 1982, the slump was worldwide with orders for 1982 down by 50 percent over the previous year. Since 1982, the worldwide shipbuilding industry has been on the rebound, though not the U.S. shipbuilding industry. Worldwide, orders for 1983 were 20 percent above 1982, although only 36 percent of 1977 construction.
- Large sums in the U.S. Navy shipbuilding program are directed at a few qualified yards. These monies are not adequate to fully occupy U.S. shipbuilding capacity nor do they require additional or new capacity.
- Termination of operating and construction subsidies and the indefinite extension of Amendment 615 to the Merchant Marine Act of 1970 (build foreign privilege) adversely affect an already atrophied merchant ship demand in the United States.
- There are also no effective incentives for the replacement of obsolete vessels in the domestic (Jones Act) fleet.

In short, capital formation is greatly affected by the failure of the demand side of the supply-demand equation to supply the shipyards with the sales revenues they need. The greatest incentive to capital investment in the industry is long-term, steady profit opportunity, which may result from a healthy orderbook or possibly favorable Navy acquisition policies.

A strong economy can be a great boost to capital formation in the shipbuilding and supplier industry. Keeping inflation and interest rates under control, stabilizing employment levels, and promoting macroeconomic (e.g., taxation) incentives can go a long way toward stemming the further deterioration of the shipbuilding and supplier industry. Most analysts agree that measures such as accelerated

depreciation schedules, investment tax credits, cutting corporate income taxes, and promoting cooperative R&D would create an improved climate for capital formation in all industries.

If shipbuilding in America is vital to national security then the industry must be sustained. At what size and cost? Shipyards need a work load to remain in business. Navy peacetime construction employs a minimum number of shipyards, but, for emergency mobilization many more yards would be required. The issue then is how to employ gainfully the remaining capacity. Following is a review of approaches to stimulating demand for ships.

Subsidy

Demand for ships can be created by the government by direct or indirect subsidy. Direct subsidy has, in fact, been national policy. Direct subsidies in the form of construction subsidies to shipbuilders and operating differential subsidies to ship operators amounted to $9.2 billion from 1936 to 1980 (Maritime Administration, 1980). Since World War II, subsidy funds have been available in amounts that have supported only a modest commercial ship construction workload. To obtain a share of this work, shipbuilders bid low and made little or no profit; many suffered losses. The subsidy program was insufficient in amount to create a market large enough to permit capital generation by U.S. shipbuilders, and thus perpetuated a status quo of mostly marginal producers. Direct subsidies, which have now been curtailed, could have been a most useful tool for modernization and innovation if they had been suffiсent to create a good marketplace and had been linked to continued industrial competitiveness and innovation.

While the construction subsidy program did not make the shipbuilders more productive, it should be noted that it did make the United States a leader in developing productive ships, such as container ships and roll-on/roll-off ships.

Indirect subsidies include government build and charter programs and cargo reservation policies (Congressional Budget Office, 1984). A government build and charter program would create demand for shipbuilding, while also addressing defense/mobilization requirements (presumably the government would build and charter militarily useful ships). The construction activity would create some jobs, contribute to sustaining or improving shipbuilding manpower, and would also generate some tax resources, which would partially offset the expenses of the program.

Approximately 2 percent of total U.S. maritime cargoes are government impelled, yet this represents half of all U.S. shipowners' business. Proponents of cargo reservation assert that reserving cargo for U.S.-built, -owned, and -operated ships with tax credits to the shippers paying the difference in costs between using foreign and U.S. ships would provide a market for U.S. ship owners in competition with those in other nations. In turn, the ship owner's need for ships would encourage U.S. shipyards to compete for the business of building those ships. By regulating the percentage of increase in reserve

shipments, shipbuilding activity could be increased or decreased as needed to maintain an industrial base. Productivity would improve due to continued orders.

Product Diversification

An alternative policy, would be to find more work that can be done and more products that can be produced cost-effectively in or near shipyards. In some instances in Japan, up to 80 percent of shipbuilding companies' products are not related to shipbuilding or ship repair (Kim and Sakiyama, 1983). In May 1984, for example, one large Japanese shipbuilder was producing a mix of products, including commercial car carriers, bulk product carriers, submarines for the Japanese defense force, large slow-speed diesel engines, large steel structures such as bridge sections and land-based nuclear power plant containment vessels, and simultaneously carrying out ship repairs for both commercial and naval vessels. Despite a declining workload associated with current worldwide market conditions, this shipyard's productivity has shown continual and substantial improvement since 1975.

A diversified range of products and markets exists that could be addressed by U.S. shipbuilders. Table 5 shows estimates of the potential markets for products that could possibly be produced by shipbuilders.

TABLE 5 Estimated Diversified Markets Which Could Be Addressed by Shipbuilders

Product	Estimated Market[a] (5-Year Cumulative)
Bridges/roadbeds	300 billion
Piping/power plants	10 billion
Warehouses	10 billion
Sewer pipe/tunnels	50 billion
Pre-fabricated hotels/motels	10 billion
Condominiums (modular)	10 billion
Oil rigs/oil refineries	50 billion
Trash incinerator	100 billion
Plants (needed in nearly every U.S. city)	
Commercial ships	$ 10 billion
Navy ships	88 billion

[a]The estimates are of total national markets. Transportation costs and size restrictions on components to be delivered by barge, rail, or truck would make shipbuilders uncompetitive in many instances.

SOURCE: Ross, 1984.

Obviously, there are markets for numerous industrial products, when they are produced competitively using advanced technological systems.

Fabrication of alternative products is not a new concept for shipbuilders. Some of the Golden Gate Bridge was built in a shipyard. Other shipbuilders have, from time to time, built railroad cars. One shipbuilder is building trash incinerator plants using modular construction methods which make use of advanced manufacturing systems.

While the market potential is large, still the means of serving the markets must be internationally competitive and efficient. Thus, a major element in a solution beneficial to business, labor, and government is the production of various products, using the same, or more advanced, technology and equipment than is used by foreign competition. Fortunately, the production management and group technology-based changes being implemented in progessive U.S. shipyards permit achievement of nearly optimum production efficiency while producing different interim products in varying quantities.

The concept of product diversification is attractive because it offers a business-based alternative to subsidy. The idea has received considerable attention (Ross, 1984), yet a number of issues remain to be addressed. Historically shipbuilders have fabricated other products as an antidote to hard times and then returned to shipbuilding as soon as there were new opportunities. Nor has product diversification ever been encouraged by the government. These factors have led to shipbuilders alternately entering and withdrawing from alternative markets in response to business and other conditions. The absence of commitment has had a chilling effect on potential customers.

Another concern pertaining to new markets is that, in fabricating alternative products, the shipbuilders will compete with other segments of the metal fabrication industry. Thus, the question of overall demand for metal fabrication needs to be addressed, as well as the relative importance of defense and nondefense indsutries to the nation.

An additional issue is that the market structures for the diversified products are very different from the shipbuilding market. The naval shipbuilder has but one customer, or at most a handful of customers, to which business strategies and systems are tuned. A shipbuilder who tried to move into other products such as highway bridges or trash plants would find himself addressing the requirements of literally thousands of potential customers. The dichotomy of the two types of markets is such that at least one source has suggested that separate companies would have to be created by shipbuilders to move into diversified products (Ross, 1984). The separate companies would employ the marketing strategies and business systems that are most appropriate to the separate markets, while shipbuilders and the new companies would share shipyard design and production facilities.

Not unrelated to these issues is the prevailing attitude in the shipbuilding industry that the concept is not new and has failed. Part of the reason for past failures has been the lack of adequate business planning for different markets. For its part, government can take steps to create a favorable climate for shipyard diversification.

This is a topic of congressional deliberation[2] and is related to the national debate on industrial and technology policy (Task Force on High Technology Initiatives, 1984).

Foreign Military Sales

Another opportunity to increase demand for U.S. shipbuilders' and suppliers' products is to develop additional sales overseas. The U.S. government has to approve foreign sales of military hardware, and has been less supportive of foreign sales of naval vessels than of other military hardware such as aircraft.

Sales to NATO

Key NATO allies have shipbuilding industries of their own, which they have elected to protect for national interests. Germany recently built 6 frigate class vessels in its yards; the Netherlands 12; and new U.S.-built combatants is minimal. Furthermore, most foreign navies, unlike the United States, maintain their own in-house systems integration capability which gives them the ability to shop worldwide for shipboard equipment, ordnance, and electronics. These foreign navies have greater industrial and competitive flexibilities than can be offered them by a U.S. shipbuilder. Despite the slim possibility of NATO orders being placed with U.S. shipbuilders, many NATO vessels are outfitted with U.S.-manufactured combat systems.

Sales to Navies of Other Countries

While U.S. shipbuilders presently have no possibility of competing successfully for foreign commercial construction, that is not the case for naval construction. The complexity and high weapon-sensor content of naval vessels permits U.S. shipbuilders to be competitive. Many developing countries do not build their own naval vessels and the worldwide exports of naval vessels to non-eastern bloc countries exceeded $3.4 billion per year in recent years. U.S. shipbuilders have barely participated in this market. If the Navy were to encourage and assist in enlarging this export potential, U.S. shipbuilders would add much needed volume to their order books.

Public Shipyards

The Navy's public shipyards are dedicated primarily to the repair, overhaul, and conversion of combatant naval vessels. Their workloads

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[2] H.R. 3399 in the 98th Congress.

are expected to grow substantially between now and 1990. The public shipyards have reduced reserve capacity for other work, including new ship construction.

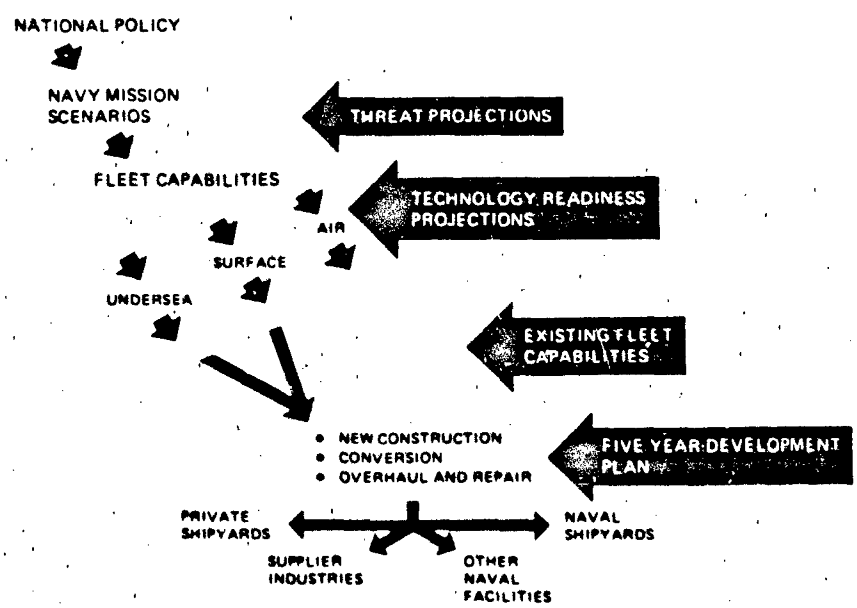
The public shipyards require substantial investment in modernization within the next decade. Deliberations concerning the modernization of public shipyards could also reopen to examination the long-standing policy that new ships will be constructed in private shipyards.

NAVY FORCE AND ACQUISITION PLANNING-- EFFECT ON SHIPBUILDING INDUSTRY

Throughout the U.S. Department of Defense, the basic policy document guiding the acquisition of major weapons systems such as ships is the Five-Year Defense Plan. The objective of the planning process (see Figure 3) is to determine what to buy and when to buy it. Thereafter, numerous administrative procedures control the acquisition process.

The planning process that culminates in the Five-Year Defense Plan is fundamentally tactical in nature. Its purpose is to develop a response to perceived and real threats through changes in the force structure. Consideration of the effects of defense procurements on

FIGURE 3 Navy Five-Year Defense Plan development sequence.

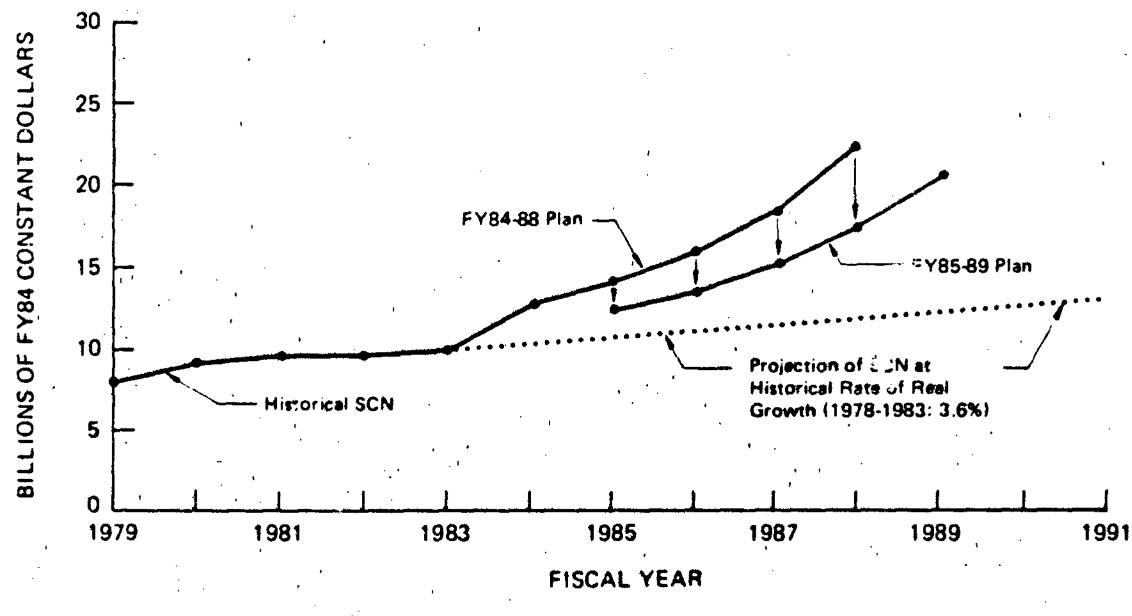


SOURCE: Ramsay, 1984

the private sector enters into the Five-Year Defense Plan to the extent of ascertaining that the industrial base can accommodate the military requirements and, in the event of a disparity, implement alternate remedial actions such as the defense priority system. The other interrelationship, the effect of the plan on the health of the industry, is not the subject of special analysis or concern. Furthermore, despite some consideration given by the Navy in the initial formulation of the Five-Year Defense Plan to technical and production feasibility and to grouping and phasing for most economical procurement, the Five-Year Defense Plan must run a gauntlet of Department of Defense and congressional approvals. The final congressional appropriations, which implement the plan, invariably differ from those proposed (see Figure 4).

Analysis of the utilization rates of industrial capacity in the United States leads to the belief that there is significant excess capacity in many industrial sectors of the economy, including the

FIGURE 4 Navy shipbuilding and conversion budget (SCN): Five-Year Defense Plan vs. actual outlays.



SOURCE: Figure developed by Georgetown Center for Strategic and International Studies, using data from NAVSEA.

shipbuilding and supplier industry. Given historical cost trends within the industry and assuming that the Navy ship construction (SCN) budget governed by the Five-Year Defense Plan averages between $10 billion to $15 billion a year, material suppliers, subcontractors, and other vendors will receive some $6 billion to $9 billion of this per year in meeting the requirements for naval vessels. In terms of the general economy, this amount is a relatively minor sum that the economy should absorb with little or no difficulty. Given the size of the economy, any expectation of spot shortages or an undue lengthening of procurement cycles except for very highly specialized products such as nuclear power plants would be misleading at the present time.

When there is slack in the economy, lead times tend to decrease. These sectors can respond by increasing output when the demand for a product is deemed by the business to be large enough to justify the reactivation of existing manufacturing capacity by (a) starting up in-place but idle machinery, (2) purchasing some limited quantities of new equipment, and (3) hiring and investing in a labor force large enough to meet this new demand.

However, the lessons of free market economics do not guarantee that the shipbuilding industry will respond because defense acquisition is not conducted in a strictly free market economy. The simple availability of the sales volume by itself is not sufficient justification for private industry to pursue defense business. Industry can ill afford to absorb the cost of hiring and training new labor if the investment cannot be amortized over a long period of time. In addition to the labor training issue, industry will consider such factors as (1) the size of the market as measured by program length, (2) the long-term profit potential of the defense market, and (3) the cash flow characteristics built into the defense procurement process before electing to compete for defense business.

Last, and most important, it seems unlikely in times of prosperity that any industrial firm will enter the defense market, if it means displacing commercial activity. Defense business today must be highly desirable incremental business if a large number of firms are to respond to stated defense needs. Thus, the bottom line of any analysis of industrial responsiveness is that industry must be assured that some of the unpredictability built into the current defense acquisition process has been reduced to satisfactory levels. The committee suggests here that supply will follow demand in defense acquisition if the demand is large enough, the demand period long enough, and the market is potentially stable enough.

Because of industry's need for a stable defense acquisition environment as a precondition to investment, there is an inherent need to factor into the defense acquisition planning process a more complete awareness of industrial behavior. As it is now organized, the acquisition process procures relatively low levels of output over an extended period of time. This type of market behavior is antithetical to the mass production orientation of much of U.S. industry.

Without proper planning as evidenced in the conditions stated above, the existing base will not respond to predictions of demand by

expanding or otherwise modernizing facilities. Further, it should not be expected that the industry will make any serious attempt at productivity improvements or to reach the economies of scale predicted for them by defense acquisition managers. The reason for this is quite simple. As the acquisition process is now organized, the defense industrial base (1) receives little benefit for striving for productivity improvement or cost saving economies of scale because profit levels are controlled and future programs are uncertain, (2) strives for productivity improvements or economies of scale by means of restructuring or reorganizing management and production operations, and (3) requires significant investment, which increases business risk substantially.

In other words, despite the projected growth in defense production, there is a serious disjuncture between the military force planning process and the industrial capability needed to support the build-up. The military needs to take greater account of the relationship between military strength and economic strength. Military needs as set out in the Five-Year Defense Plan need to be reviewed in the context of the underlying dynamics of the industrial sector.

There is nothing in the Five-Year Defense Plan for naval ship acquisition that suggests to the business community that the U.S. shipbuilding industry is entering a period of solid growth. From a businessman's perspective, the signals are mixed inasmuch as the administration is calling for both an enhanced Navy shipbuilding program and a collateral downgrading of its commitment to the merchant fleet by not funding construction differential subsidies and not authorizing new Title XI mortgage guarantees. Similarly, no encouragement has been forthcoming for the export of ships, particularly naval vessels.

A related caution to the businessman is that the amount of shipbuilding spending set forth in the Five-Year Defense Plan fluctuates from year to year and, in any event, is significantly greater than actual outlays (see Figure 4). The prudent investor will calculate the risk of investment on the historical data.

In searching for an understanding of the problem, it needs to be recognized that the privately owned U.S. shipbuilding industry has the ability to establish its own priorities, including the ability to expand or contract, and to modernize or become more productive. This, however, is affected by the pattern of conglomerate ownership that prevails in this industry. Most large shipbuilders are divisions of major corporations, which have many alternative investment opportunities.

Compounding these difficulties are force planning procedures that emphasize buying from "what is" as opposed to "what should be." The additional Navy role of directly stimulating productivity improvement in industry is not prominently pursued.

To overcome these deficiencies, it seems evident (if a viable shipbuilder and supplier industrial base is to be maintained) that the Five-Year Defense Plan cannot remain solely a force planning document. More needs to be known about how the monies to be spent for military equipment can best be filtered into the marketplace in a way which stimulates the creation of market mechanisms that motivate the

development of a responsive, technologically capable, financially independent, and productive defense industrial base.

Military planning and economic planning need to be synchronized more in the future. Without this, unnecessarily high costs for military equipment are incurred, as well as delays in the production and ultimate deployment of the weapons systems needed by the military services.

MOBILIZATION PLANNING

Without national consensus on the size and shape of the U.S. shipbuilding mobilization base, imprecise notions of what is adequate act as a disincentive to new technology-oriented capital formation. From a strictly theoretical point of view, the concepts of the maintenance of surge capacity and the rationalization of the shipbuilding base work at cross purposes. The presence of "extra" capacity during peacetime in an industry already burdened with overcapacity can only act as a drain on productivity. Many shipbuilders and suppliers continue to operate on marginal demand, based on expectations of an increased national mobilization base requirement.

A reexamination of mobilization requirements is under way and is likely to result in the definition of a smaller number of shipyards being vital to the national interest. The disparity between that which is economically rational and that deemed necessary for mobilization will persist. Once a policy has been articulated concerning the number of shipyards necessary for the defense industrial base, shipbuilders can make informed decisions about remaining in or leaving the new construction industry, diversifying, and making capital expenditures for the future.

EFFECT OF CONTRACT TERMS AND CONDITIONS ON INVESTMENT, PROFITABILITY, AND PRODUCTIVITY

The Navy contract is what the shipbuilder (or ultimately, his supplier) uses to convince the investor that there will be satisfactory return on investment. In the committee's view, a great deal can be accomplished to improve shipbuilding productivity by improving business conitions, at little cost to the government. This section reviews the terms and conditions of shipbuilding contracts to show their very great effect on the attractiveness of investment in shipbuilding, on profit, and ultimately on productivity.

Multiple-Ship and Multiple-Year Procurement, Long-Lead Funding, and Economic Production Runs

The necessity of coping with inadequate quantities of purchases and substantial manufacturing lead times forces shipbuilders and suppliers

to consider innovative approaches to purchasing a larger number of units at one time to take advantage of economies of scale and also to support master construction schedules, especially the shorter schedules associated with modern ship production methods.

Multiple-Ship and Multiple-Year Procurement

Section 909 of the U.S. Department of Defense (DOD) Authorization Act of 1982 establishes statutory authority for the purchase of quantities not in excess of known requirements for up to 5 years in advance of need, in support of DOD 5-year defense plans. Provisions state that multi-year procurements may be used for major systems acquisition; advance procurements may be made to obtain economic production lots, cancellation ceilings may include recurring and nonrecurring costs; and notification to Congress is required for ceilings over $100 million.

Single- and multiple-ship procurements are funded completely when authorizations and appropriations are made by Congress. Multiple-ship acquisition need not be synonymous with series construction. Batch orders for similar ships (e.g. auxiliaries) as an alternative to identical ships may provide a means of increasing the number of multiple-ship procurements. Multiple-ship procurements can pose problems in the budgeting and appropriation cycle by creating a large 1-year increase in Navy ship construction funds as did the two-ship Nimitz class aircraft carrier acquisition in fiscal year 1983.

Multiple year procurements receive appropriations from Congress only for the first-year lot buy as well as cancellation funds for the out-year lots. Congress must approve funds each year for that year's lot if the program is to continue. In spite of the demonstrated advantages, and of the passage of Section 909 in 1982, Congress has been very reluctant to approve large multi-year procurements.

Case studies in Appendix C clearly demonstrate the importance of long-term economic-lot-size funding commitment to productivity improvements. A 17-ship procurement in 1966 enabled National Steel and Shipbuilding Company (NASSCo) to extensively expand and modernize its shipyard--in fact, NASSCo's bid on the project included the cost of shipyard expansion in the package price (Carpenter and Finne, 1972). Without the expansion, NASSCo would not have been able to build the ships at the rate specified by the government and could not have bid. The series procurement of FFGs from Bath Iron Works and Todd Shipyards in the late 1970s, and the introduction of contracts with provisions for enhanced profit with improved performance, enabled the shipbuilders to reorganize their ship production processes to take advantage of advances in ship production methods, and to make extensive capital improvements. These developments resulted in significant improvements in cost and schedule performance on later ships.

Long-Lead Funding

Some ship components are large and complex, and take many months or years to design, order, and construct before they can be installed on a ship under construction. The lead time for some components actually can be longer than the relatively short time that the ship is being built. The provision of long-lead funding is necessary to provide material support to complex master construction schedules.

Long-lead material funding has been made available on a selective basis for a number of years. The record of advantages in terms of productivity improvement is clear. It supports shipbuilders' construction schedules, provides suppliers with opportunities to level-load their operations, overcomes some of the uncertainty surrounding congressional appropriations, and supports the earlier engineering and production planning activities necessary as shipbuilders apply modern ship production methods. What is not clear is why the Navy does not use long-lead funding to a much greater extent. Notwithstanding its advantages, the use of long-lead funding is constrained by the necessity of congressional concurrence in some instances, and, especially in areas where technology may be developing at a fast pace, the objective of purchasing the latest, most advanced equipment.

Option Procurement

Funding uncertainties surrounding multi-year naval ship acquisition programs create major problems of acquisition and building strategy for the Navy, its prime contractors, and suppliers. The essence of the dilemma is whether the cost of construction should be estimated on a run of one ship or a series of ships. Just as multiple buys of ships have historically been advantageous to the Navy, quantity of business bears heavily on the unit cost of shipbuilders and suppliers.

Some shipbuilders employ a strategy of requesting estimates on an option basis, which takes advantage of the cost-saving potential of multiple-unit purchase, while still taking account of the seemingly inevitable Navy authorization uncertainty. Option procurement assumes that there will be at least one and possibly as many as (x) units constructed. Suppliers are requested to estimate prices for follow-ship procurements in concert with their estimates for the lead ship procurement. Delivery dates for the shipsets are estimated. Other uncertainties addressed are compensation for inflation and adjustment for engineering changes.

Option procurement creates additional estimating, bidding, and proposal review work for shipbuilders and suppliers, but it has many advantages. It provides firm budget figures for follow-ship equipment and offers some opportunity for taking advantage of quantity purchases. (From the supplier's viewpoint, the advantage is a more stable workload.) Using option procurement on a flight of seven ships, one shipbuilder was able to avoid nearly $9 million in costs that would have been incurred if items for each ship had been procured separately.

Another advantage is the shortening of the procurement award cycle. The option strategy also minimizes technical and management review of equipment selection. A last major advantage is that option procurements provide a tool to obtain a more advantageous price as well as other benefits such as product or manufacturing improvements that would not be as likely on a single ship purchase.

There are certain problems in utilizing option procurements. One is deciding the weight to apply in evaluating subsequent shipset prices. It must be remembered that usually only one ship is funded at the time of bid evaluation, and there is no guarantee that more than one ship will be purchased. The same dilemma faces most bidders. Another disadvantage is, after selecting the source for the lead ship, it becomes increasingly difficult to change suppliers because of standardization and the necessity of making engineering changes to accommodate different suppliers. Suppliers can take unfair advantage of this by pricing the first lot lower and subsequent lots somewhat higher. Yet another potential disadvantage arises from early commitment to delivery dates, which may not be realistic or cause inventory disruptions. Finally, shipyards, which are facilities-limited, may be unable to bid for additional contracts which are funded but require facilities reserved for an option on an earlier contract which might never be funded. Although these potential difficulties and disadvantages exist, the use of options has been found to be highly advantageous to both shipbuilders and suppliers.

Spare Parts

The after-market, or the provisioning and repair of parts, is an essential element of the Navy suppliers' marketing plans. Often, interest in naval shipbuilding programs is prompted more by the expectation of continuing business rather than initial volume. In turn, the supplier's commitment to continue to service the after-market is of great value to the shipbuilder and the Navy. The assurance of a lifetime source of supply for parts is a major benefit which is difficult to quantify.

The Navy does not authorize the shipbuilder to buy on-board spare parts until the coordinated shipboard allowance list is developed. This occurs years after the procurement of material for ship construction. This sequence makes it impossible for the Navy to take advantage of the potential savings that would result from larger quantity purchases.

Granted not all on-board repair parts should be ordered concurrently with the original equipment. Items with a relatively short shelf life, such as "o" rings and gaskets, are better purchased closer to time of need, after the coordinated shipboard allowance list has been prepared. Nevertheless, many parts for on-board repair, such as impellers and wear rings for pumps, could be purchased by the shipyard along with original equipment. Considerable savings could be achieved if the Navy were to authorize some on-board repair parts concurrent with the purchase of initial construction equipment.

Centralized Procurement

The Navy recently awarded contracts to shipbuilders for the conversion of commercially acquired vessels to form the nucleus of a Rapid Deployment Force. An element of the acquisition plan has been the centralization of material procurement, with one shipyard serving as the central purchasing agent for the entire acquisition. Considerable savings are resulting from the larger-quantity purchases. Similar strategies have been utilized on some programs and proposed and rejected on others. The Navy does not appear to use centralized procurement to the extent possible, although there are considerable potential benefits. This practice could be extended to long-lead time material procurement.

Timing of Orders

The timing of Navy business is a paramount concern of shipbuilding suppliers. Since the volume of Navy shipbuilding business for most suppliers is small, the timing of that business is critical. With proper planning, meaning 3 to 6 months' lead time in advance of order placement, manufacturers can integrate the Navy's needs into their normal business. However, the timing of shipbuilders' orders to suppliers normally is driven by the Navy's orders with shipbuilders, and the shipbuilders' resultant need for the material and ordering efficiency. While suppliers are generally aware of the status of naval acquisition programs, each shipbuilder operates to a unique production schedule making it difficult for suppliers to anticipate the timing of orders. Also, any delays in the Navy's procurement schedule will have serious consequences for shipbuilders and suppliers.

The financial stability brought about by these alternative procurement strategies provides shipbuilders the opportunity to plan for future capital investments with the assurance that these investments can be amortized out of income. The Defense Science Board has stated, "The principal benefit of such longer-term contracting arrangements is to achieve economies of scale. With greater assurance of a solid program, contractors have a much greater incentive to invest in productivity measures and to make economical buys from vendors and subcontractors" (U.S. Congress, 1980).

Incentive Contracts

For several years, the Navy has sought to have contractors assume increased risk of performance in exchange for the potential of additional profits. One mechanism for this has been the establishment of negotiated target costs in contracts for ships, and then the splitting of any lower-cost difference between the government and the shipbuilder. The split has progressed from a maximum Navy benefit of under runs, and minimum contractor risk split of 80:20 to an even

split. Contracts that include incentive provisions have encouraged shipbuilders to modernize facilities and produce ships below target cost.

In the 2 years after the Navy changed its contracts to give more incentives to improved performance, a builder of surface combatants received $40 million of what it saved the Navy as a bonus on top of its contract target profit of $95 million. From 1978 to 1983, another naval shipbuilder modernized its facilities and made numerous improvements in its ship production processes which resulted in fewer man-hours on the job and shorter construction times. With the new contract terms, the shipbuilder's improvement has been directly reflected in corporate earnings, which rose from 1.9 percent in 1978 to 8.4 percent in 1983. The improved profit picture has, of course, generated additional working capital.

Another innovation in Navy contracting directed more specifically at productivity improvement is the test Industrial Modernization Incentives Program (IMIP) (described in Appendix C).

Progress Payments

Progress payments compensate the contractor for labor, materials, and other costs incurred as the work on the contract progresses toward completion. Naval shipbuilding progress payments call for a 10 percent holdback on contract price until the project is 50 percent complete and then a 5 percent holdback until delivery. At delivery, all but a small percentage, 1 to 2 percent of the contract price or a holdback dollar figure determined during contract negotiation, is paid. The remainder is paid at the end of the guaranty period. These terms are different from Federal Acquisition Regulation (FAR) clauses, but the Navy has longstanding authority to use its own clause.

There have been recent recommendations for shipbuilders to be paid on the standard federal terms, which would reduce progress payment percentage to 85 percent for small business and 80 percent for others. Because of interest costs, which are disallowed on government contracts, and time lags between contract performance and payment, progress payments at 80 percent would cover only about 60 percent of a shipbuilder's working capital investment. Even the current progress payment rate does not completely reimburse the contractor.

Progress payments are essential as a source of working and investment capital. Any reduction in progress payments will require the contractor to finance additional work in process, and reduce the funds available for capital investment.

Contractual Holdbacks

An important aspect of the government payment system is that the government retains portions of the shipbuilder's profit, and also the contract price for stated periods (see above). Upon delivery of the

ship, the shipbuilder receives funds withheld from progress payments, with the exception of a modest holdback for the duration of the warranty period. Under incentive contracts with target costs, the shipbuilder's profit is calculated after completion of the work, and the shipbuilder may receive a payment covering much of his profit after the delivery of the ship. The payments upon delivery may be substantial, and the sums involved may represent profit on work completed many months or even years before. For example, on some recent shipbuilding contracts for surface combatants, earnings retained by the Navy until ship delivery represented 15 percent of the total contract price. The rationale for such substantial holdbacks is not apparent.

On occasion, the Navy has released a portion of hold-back funds early for the purpose of facilitating capital investment that will result in productivity improvement without impacting a contractor's cash flow position. A submarine builder for example, recently purchased numerically controlled milling machines with hold-back funds that were released by the Navy expressly for that purpose. While the withholding of some earnings until delivery of the ship and for a warranty period makes unequivocal sense, the Navy needs to consider that the amount of hold-back funds influences the shipbuilder's cash position, the extent to which the shipbuilder has to borrow funds for working capital (thereby incurring additional nonallowable interest costs), and also funds available for capital improvements. It also makes sense for the Navy to consider, on a case-by-case basis, releasing such funds early for the purpose of productivity improvement.

Cost of Facilities Capital

In 1976, the Department of Defense (DOD) completed a study to determine contractors' profits on both defense and commercial business and to examine the relation of earnings to capital investment in assets designed to increase productivity and lower costs (Department of Defense, 1976). The study was conducted as the result of considerable concern that contractors' investments in modern manufacturing technologies and efficiency improvements for defense work was inadequate, leading to plant obsolescence, expensive labor-intensive methods and higher costs. The study found that the level of facility investment in defense contracts had been considerably lower than in comparable commercial endeavors. Also, the U.S. government realized that it was competing with commercial interests for necessary funds to modernize their respective industrial bases. It became clear that DOD procurement policy failed to recognize adequately the facility investment required for efficient operation, nor did it provide proper incentives for such investments. Consequently, two major changes were made. The first provides that the imputed cost of capital for facility investment is an allowable cost on most negotiated DOD contracts which are priced on the basis of cost analysis. The second change is that facilities investment has been added to the basic profit evaluation process.

Prior to this, the cost of capital was an unallowable cost in defense contracts. Cost Accounting Standard (CAS) 414, "Cost of Money as an Element of Cost of Facilities Capital," was promulgated by the Cost Accounting Standards Board to measure and allocate the imputed cost of capital committed to facilities used in the performance of government contracts.

The committee used an example to illustrate the effect of Cost of Facilities Capital on capital formation and its relationship to depreciation, interest, income, and the time value of money (see Appendix E). Consider a $100 million annual investment in facilities improvements (see example). With an investment tax credit of $10 million, $90 million of the investment is left to be recovered through cash flows, depreciation, and interest, discounted at an investment hurdle rate of 12 percent.

The example shows that even with the cash flow advantage provided by cost of facilities capital and also an investment tax credit, a 19 percent after-tax return on investment would be required in order to recover within 10 years the net investment of $90 million. It should be noted that a 19 percent return, relative to the norm for a typical company, appears to be quite high; however, only capital equipment is being considered in the example and working capital would reduce the percentage. Nonetheless, cost of facilities capital plays an important part in investment justification because it offsets unallowable interest.

Cancellation Guarantees

A major concern which defense contractors have in considering facilities improvements is the uncertain future of many DOD programs. To relieve that concern and encourage more capital investment, DOD has agreed on occasion to purchase, at depreciated value, those of the contractor's fixed capital assets which were acquired for use on a specific program, if that program is later cancelled or drastically reduced.

In 1977, DOD changed the acquisition regulations to provide policy guidelines and methods to protect both government and contractor interests and enable wider use of this practice. The approach has the potential for stimulating increased contractor investment in more efficient equipment. It is believed by some that if this provision is carefully used with proper controls, the cost of DOD purchased hardware could be lowered.

Cancellation guarantees are a "show of good faith." DOD has long been aware that the instability inherent in any program is among the main factors inhibiting contractors from making investments in new facilities. To the extent that a cancellation guarantee reinforces DOD's commitment to program stability, it may help to build the kind of confidence needed to attract capital.

Accelerated Depreciation and CAS 409

Revisions in depreciation allowance scheduling resulting from the Economic Recovery Act of 1981 have probably had a positive effect on the capital bases of defense contractors. Critics had long noted that among industrialized nations, the United States had the most "repressive" of all tax structures. The Act decreased the minimum depreciation life required by the Internal Revenue Service (IRS) for tax purposes to either 10, 5, or 3 years depending upon the nature of the equipment.

In addition to the Act, defense contractors have also had to comply with CAS 409, "Depreciation of Tangible Capital Assets." At the time CAS 409 was implemented, the belief was that a depreciation standard was needed because charges that were based on income tax and financial reporting practices did not provide reasonable representations of the actual cost of the equipment used on government contracts. The standard did not dictate or prohibit the use of any particular method of depreciation. Its key requirement was that the method used "reasonably reflect" the consumption pattern for the assets being depreciated.

The standard has been misread by some who contend that CAS 409 mandates depreciation periods and methodologies which are longer than those allowed under the Act. In fact, however, a more liberal approach has been taken to CAS 409 such that many companies now depreciate their assets for both IRS and DOD purposes on the same basis. In any event, efforts to revise the standard will be delayed since the Cost Accounting Standards Board, an agent of Congress, has gone out of existence. Legislative efforts to transfer its functions to the Office of Management and Budget (OMB) are under way. The DOD is supporting this transfer as part of Initiative No. 5 in its Acquisition Improvement Program.

A problem with CAS 409 arises because DOD requires contractors to charge depreciation to contracts in the same way as they do for financial reporting. Companies, defense contractors, and others generally use accelerated depreciation for tax purposes and straight line for financial purposes. Because of the restriction on charging the interest, defense contractors are concerned with the ways that invested capital can be recovered. If they could charge contracts with accelerated depreciation instead of straight line, investments would be recovered sooner. The earlier recovery would provide cash which could be used to finance additional investment and to reduce borrowings.

The DOD position is that if defense contractors were allowed to charge accelerated depreciation to contracts, contractors would receive the double benefit of both tax relief and higher cost recovery. The government is concerned with the possibility of paying more for weapons systems. What the DOD may be overlooking is that in most cases, the differences in costs is only a matter of timing, particularly for shipbuilding companies who will be principally engaged in naval construction, conversion, overhaul, and repair. Higher depreciation costs in early years become lower in later years with the gross cost to the government being approximately equivalent for the complete program.

In a sense, the government would be financing part of the contractors' investment; but in many cases this would only be true for facilities recently installed. The government would benefit through the cost and quality benefits of modernized facilities being used to manufacture defense systems.

Interest Disallowances

The FARs prohibit the inclusion of direct interest costs as an allowable cost on government contracts. This has two negative effects on capital formation. First, "going in profits" must be increased to offset this cost disallowance. Because this action increases price, it has the potential for harming the competitive position of a contractor. In simpler terms, it adds another unknown to the negotiation process and increases the business risk to which a contractor is exposed. Second, this disallowance helps to discourage the banking community from lending either short- or long-term funds to the shipbuilding industry in that it excludes from normal cash flow allowances an item which should normally be payable out of cash flows rather than profits. The disallowance is important for a large contractor but becomes even more critical for smaller, less adequately capitalized subcontractors.

PROSPECTS OF FOREIGN INVESTMENT IN THE U.S. SHIPBUILDING INDUSTRY

Foreign shipbuilders have investigated the prospects of investment in the U.S. shipbuilding industry and concluded that there are few if any legal barriers. The incentives (if any) are the potential commercial and naval shipbuilding and repair market, and the possibilities of major improvements in shipbuilding productivity.

Foreign shipbuilders have studied the experience of foreign (mainly Japanese) manufacturing companies in the automobile, electronic, and aircraft industries that have set up U.S. plants using U.S. labor with foreign management and operating procedures. Some examples have been in the defense manufacturing sector. By and large, these plants have been able to improve productivity in comparison with existing U.S.-managed plants, using U.S. labor. Their production costs similarly compare favorably with those of comparable foreign plants.

A reason for their interest could be the desire for an industrial and asset foothold in the United States. Foreign shipbuilders have already successfully marketed their technology transfer expertise to major U.S. shipbuilders, including some naval shipbuilders. A foothold in U.S. naval shipbuilding would provide a short cut in technology transfer, which these companies expect will permit them to stay at the forefront of technological development.

Legally, there are few restrictions to foreign ownership and even fewer to foreign investment in U.S. shipbuilding. The only exceptions are those dealing with access to classified information. Foreign-owned and -managed shipyards may be barred from combatant ship construction,

but this, does not prevent foreign investors from owning up to 50 percent of a shipyard, as long as the shipyard has U.S. majority ownership and is managed and operated by U.S. citizens. There are some exceptions, and foreign-owned U.S. subsidiaries which are U.S.-managed and -operated may qualify for government contracts in addition to commercial shipbuilding orders.

Various approaches to foreign investment in U.S. shipbuilding are available, such as:

- Purchase of an existing U.S. shipyard or majority participation in ownership.
- Purchase of a minority share in a U.S. shipyard or in the shares of the owning company.
- Construction of a new shipyard financed by foreign investment.
- Joint venture with U.S. company or investors in purchasing an existing shipyard or building a new shipyard.
- Investment in the rehabilitation or improvement of a U.S. shipyard, including technology and management transfer.
- Investment in specific improvements or activities related to shipbuilding.
- Investment in one- or two-way technology transfer.

In addition to investment by foreign shipbuilding companies, a number of other vehicles for foreign investment in U.S. industry have recently been used, such as:

- Sale and leaseback of facilities.
- Purchase of minority shareholding.
- Venture capital investment on a risk basis.
- Transfer of foreign equipment and know-how against part ownership or share of savings or profits.

There are many more approaches which may be of interest to or involve foreign banks, investors, or industrial corporations. However, as long as the major U.S. shipyards are profitable there is little reason for them to seek either a foreign partner or an outright sale, unless their corporate owners decide to divest.

4

MODERNIZING SHIPBUILDING TECHNOLOGY: INTEGRATING ENGINEERING AND PRODUCTION TO SUPPORT ZONE-ORIENTED SHIP DESIGN AND CONSTRUCTION

There is a quiet, relatively unpublicized transformation occurring in U.S. shipyards today, oriented toward decreasing the man-hours required to build ships. This is being achieved by shifting away from systems-oriented shipbuilding practices toward zone-oriented design and construction practices which emphasize the concept of grouping work by process category and accomplishing each in more effective ways. The objectives of this chapter are to document that zone-oriented construction techniques are in present-day use by naval shipbuilders, to explain how the transformation of U.S. shipbuilding practices is clearly in the Navy's interest, and to explain how the Navy can take full advantage of the transformation.

The term "zone-oriented" refers to an approach to ship design and construction processes that is based upon considering the total ship as a combination of several zones in which the complexity of equipment and systems are different, so that the construction techniques, and thus the required design documents, can be optimized for each zone. The early design stages and the operational testing phases of construction are still primarily system-oriented, but the installation design stage and the fabrication, assembly, and installation phases of construction are zone-oriented.

Modern zone-oriented shipbuilding methods have roots that extend to the series construction practices developed in the Second World War, the development of modern Japanese shipbuilding methods, and Navy emphasis on modular construction beginning in the 1960s. The first two developments have been described in detail (Chirillo and Chirillo, 1984). Starting in 1965, Navy top management introduced many innovations in ship acquisition including concept formulation/contract definition, total package procurement, modular construction, and (to an extent) series construction of standardized ships. These innovations which enabled changes in engineering and production methods were reflected in a number of ship acquisition programs including the FDL, LHA, and DD963 programs.

The implementation of zone-oriented methods has been strongly influenced by the results of studies by the Maritime Administration and by some shipyards with Maritime Administration and Navy support under the joint government and industry National Shipbuilding Research Program (NSRP). They involve application in the United States of practices developed over 30 years by the Japanese shipbuilding industry.

Zone-oriented ship construction techniques encompass:

- o Organizing work by common or similar work processes and emphasizing production line concepts for hull construction and zone outfitting.
- o Providing design, material, and planning information to production personnel in a form which is oriented to the production process and stage of construction involved.
- o Providing material to production personnel in ways that simplify utilization and installation of that material.
- o Improving the organizational structure of shipyard departments, to accomplish most effectively the above.

The zone-oriented methods being introduced differ significantly from the conventional system-oriented practices of U.S. shipbuilders. Zone-oriented methods have been described in detail in a series of NSRP reports (Chirillo, 1979, 1982a,b, 1983a, b; Okayama and Chirilio, 1980). They have significant labor-saving effects on any type of ship, including combatants, for one ship of a class. Zone-oriented methods have recently been tried successfully in the changing of combat systems in ship overhauls. Certain techniques can be applied to any ship's contract design documents with significant production cost reductions. (That is, it is not necessary to re-engineer a contract design package to achieve production cost savings through the improved construction techniques.) However, the savings to be achieved can be significantly greater when the contract design is optimized for zone-oriented construction methods.

ADVANCES IN SHIP DESIGN AND CONSTRUCTION PRACTICES

During the preliminary and contract design phases, the elements of a ship are treated as systems. In the past, it was customary to carry the systems approach through the detailed design process, and then to construct and assemble the ship by system. After World War II, however, the Japanese shipbuilding industry applied industrial engineering concepts that had been developed in the United States, and eventually abandoned the system-oriented ship construction approach. The new approach resulted in drastic reductions in man-hour expenditures and building schedules. The zone-oriented construction techniques that have been applied to shipbuilding and refined by the Japanese, and which are being applied and developed further by U.S. shipbuilders, concentrate on building a smaller section of the hull, called a block or unit, and then "outfitting" (i.e., installing all piping, ventilation ducting, etc.) as it is built. Outfitted units are then joined together to complete the ship. Some systems, primarily electric wiring, are more advantageously installed after the ship is more fully assembled.

Another important innovation is "packaging," sometimes called outfit module construction. This technique flows from a recognition that many individual pieces of equipment which are interrelated, such as pumps, motors, and controllers, can be mounted together on common foundations, assembled together as a "package," and installed in place

as a single entity during the major assembly process. Through proper design, a large proportion of equipment, destined for very congested areas, can be packaged and assembled in a shop, instead of in a confined space within a hull. Packaging yields significant reductions in man-hour expenditure, and improvements in quality. Many packages of equipment can be hydrostatically and electrically tested before installation, with consequent ease of correction of any problems.

A number of advantages are achieved through these revised construction and assembly techniques. First, emphasis is placed on organizing production lines. Each is subdivided into stages, so that work of the same type is performed in the same place. Plates are welded together at one location. Stiffening members are welded to the plates at another location. Small structural assemblies are welded together at another location to make larger structural assemblies. At the most efficient time for installing piping, the assembly is moved to a location where this type of installation is accomplished. In this way, the personnel at each work station do the same type of work each day, gaining proficiency and minimizing lost time. Necessary tools are at hand. Waits for cranes and other sources of delay are reduced. Necessary materials are delivered to the work site. Everything is controlled to make the construction/assembly process as efficient as possible.

Concentration on one process at one site (or at several specifically designated sites) is possible even on one ship, because so many processes are repeatedly accomplished on the many units which make up the ship.

A necessary element of the technique is the identification and classification of each unit of the ship. Units are classified by complexity of shape, location on the ship, or other criteria which control how, when, and where they are to be constructed and assembled. Dividing the ship into units is the responsibility of the production planning organization, but many other departments of the shipyard also are involved in production planning.

Accuracy is more critical with zone-oriented methods than with system-oriented construction. When the hull is assembled on a system basis, deviations, such as excursions from circularity in a submarine, can be accommodated by force fitting to some extent, because components, piping, and stiffeners are not installed at the time that the hull butts are made; therefore, the hull structure is more flexible during assembly. There is also greater access for heavy fitting devices. With zone-oriented methods, special attention has to be paid to components that support structures and machinery that crosses the butt weld because they are in two different units and will have to be installed to a tolerance that will still be acceptable after the units are joined. Similarly, pipe systems that run across the weld joint have to be targeted accurately, so that they can be joined after the sections are welded. Packaged units also are inherently stiff, so that force fitting becomes much less feasible.

From the Navy's standpoint, greater accuracy translates into improved performance, especially concerning noise and shock requirements. U.S. shipbuilders generally have expended some effort to

monitor the accuracy of their production processes. Accuracy programs are most powerful when they employ statistical analysis of accuracy variations. Statistical analysis provides a means for continuously improving design details and work methods so as to maximize productivity (Chirillo, 1982a).

These advances in ship production technology were developed through careful study of the processes involved in building ships and development of improved sequences and techniques for accomplishing those processes. Industrial engineering concepts were essential, as opposed to ship design engineering concepts. However, the improvements cannot be achieved without changes in ship design and engineering, and the documentation of requirements that results from these activities. Figure 5 illustrates advances in ship production technology.

A ship is designed in stages. The feasibility design stage, normally accomplished by the Navy with the assistance of consulting naval architects, establishes the overall performance and cost-driving parameters of the ship, such as length and displacement, by comparison and analysis of various design concepts. The preliminary design process develops an additional level of detail, allowing identification of the effects of variations in major ship systems. Contract design represents another iteration of the design at yet another level of detail. The results of contract design are a set of specifications and drawings, which define and depict the ship in sufficient detail for the shipbuilder to develop an estimate of the cost to build the ship.

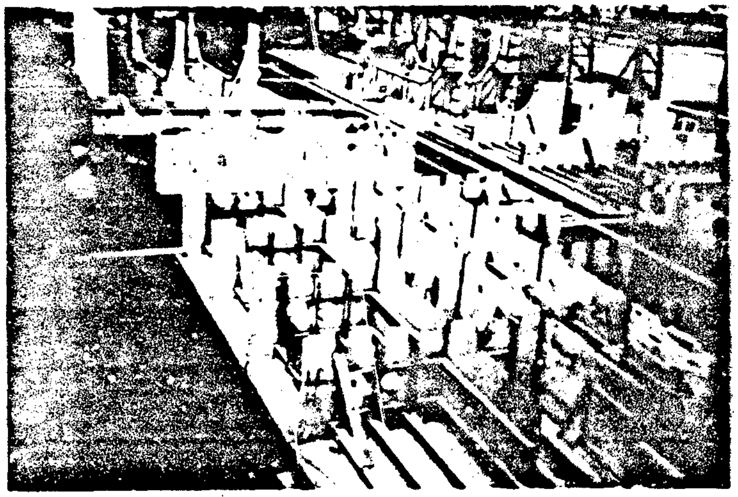
These design phases are necessarily systems-oriented, since the required performance of each system must be defined and thoroughly integrated with all other systems. However, since each phase provides more detailed definition of the ship which is to be built, each phase should take the construction aspects of the design into greater consideration. The relative location of various pieces of equipment which make up a system can and should be considered, even during preliminary design, with the concepts of packages and units in the designer's mind. Otherwise, the shipbuilder may need to redesign portions of the ship to suit his building strategy.

After the Navy awards a contract to build the ship, the shipbuilder, or naval architect under contract to the shipbuilder, undertakes the detailed design of the ship. During this phase of design, the final construction drawings (those from which production personnel actually work) are developed.

The implementation of zone-oriented ship construction methods has necessitated a transition stage for grouping information by zone following the system-oriented key plan, or functional design stage to facilitate zone-oriented detail design.

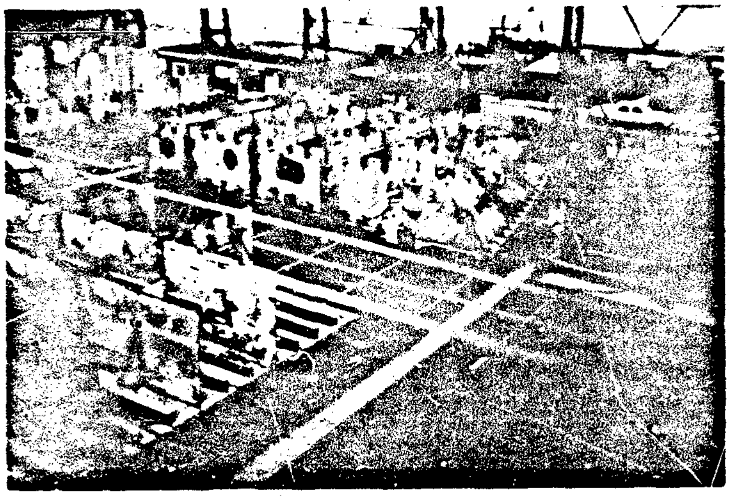
The key plan stage involves a final iteration of the design of every ship system. The hull structure is defined in detail, and the appropriate weight, strength, and stability studies are accomplished. Diagrams defining the size and interfaces of every piping and machinery system are completed. These "key" plans provide the final system-level description of the ship and are useful for ascertaining that all desired operational and regulatory requirements have been covered satisfactorily in the design.

FIGURE 5 Advances in ship production technology.

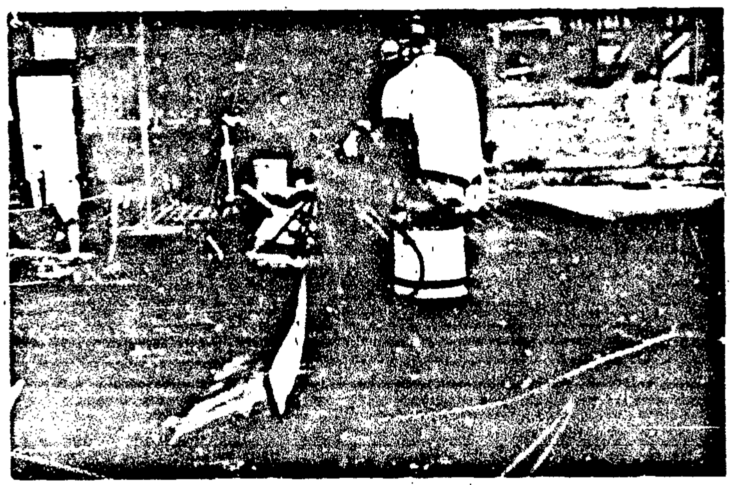


a. Process Flow. When assembly problems remain unchanged and when work contents of each are about the same, all conditions exist for operating a production line. As many as 60 percent of the blocks required for erecting the hull of a naval auxiliary could be classified as flat blocks. The process flow shown is divided into work stages for initial assembly, outfitting, main assembly, and, following turnover, final assembly. When work is so organized, learning curves are obtained per process flow with far more meaningful productivity indicators (e.g., man-hours/ton, man-hours/welding length and tons/meter^2/month) than available with traditional hull construction methods.

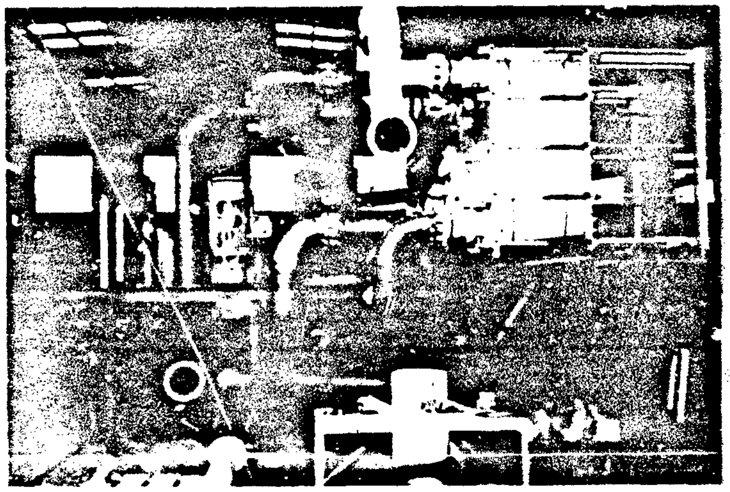
b. Sub-Block Assembly. A specific platen area is dedicated for just-in-time assembly of sub-blocks (usually 1-week buffer) to support block assembly. The work is divided into stages for layout, fitting, welding and distortion removal by line heating.



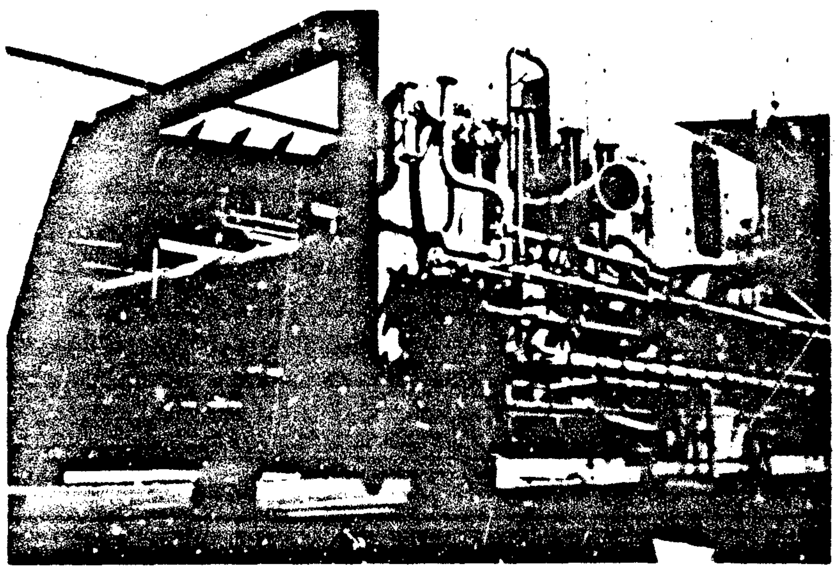
c. Pin Jigs. As shown in the background, a pin jig is being used to just-in-time produce an accurate curved bottom shell for the flat block which appears in the photograph's center. As hulls for the DDG-51 class are to feature lots of curvature for speed in a relatively high sea state, pin jigs are essential for productive manufacture of accurate panels. Pin jigs consist of adjustable-in-height posts which are arranged in rows and columns equidistant from each other. When each post is adjusted in accordance with loft-furnished heights, an accurate three-dimensional representation of a required curved surface is obtained. Usually 1 to 1-1/2 man-days are required to reset a pin jig for a particular requirement. The need for significantly more expensive traditional mock-ups is eliminated.



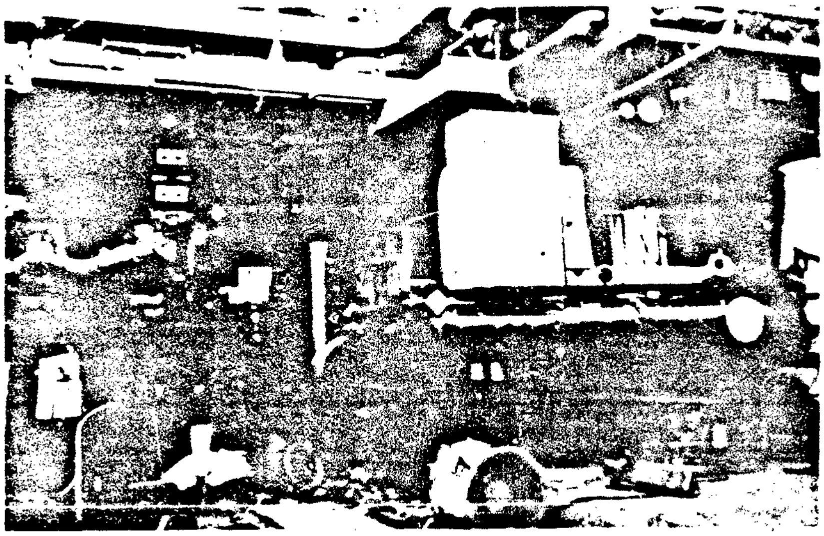
d. Line Heating. Systematic heating and cooling is used to accurately produce required shapes. The accuracy obtained by such methods minimizes force fitting for the purpose of reducing locked-in stresses which cause distortion after welding.



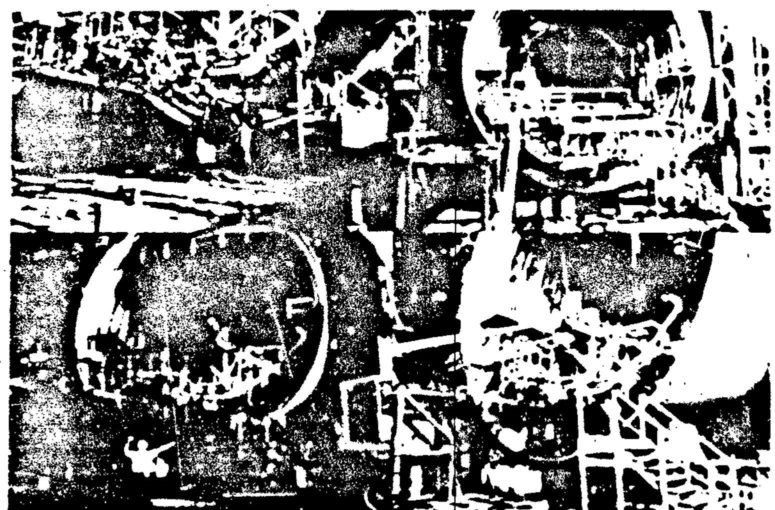
e. Outfitting On-Unit. On-unit outfitting enables most assembly and painting to be performed in shops where work circumstances, particularly safety, quality and productivity, are greatly enhanced.



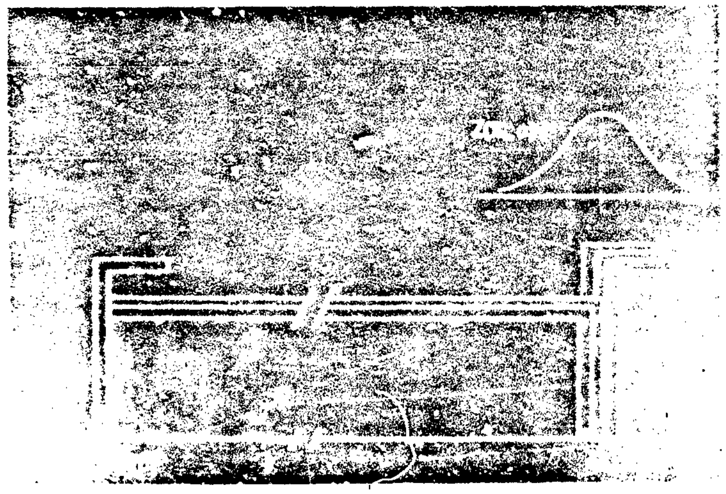
f. Outfitting On-Block. This second major outfitting stage is subdivided into outfitting on-ceiling (as shown) and, following turnover, outfitting on-deck.



g. Zone-Outfitting On-Board. Looking forward in an engine room showing outfit units and outfitted blocks landed during the first erection shift. Less than about 15 percent of engine-room fittings have yet to be landed.



h. Zone Outfitting. End loading machinery spaces in a submarine.



i. Accuracy Control. When a production process is carefully managed, variations occur in a normal pattern. Once a normal curve is obtained, verification that the process remains in control can be readily achieved by nominal random sampling. Employing the theorem of variance, the most effective shipbuilders add normal distribution from previous work processes in order to predict how they will merge at a later process for a particular design detail.

Up to this point, there is little difference in the design process or design documentation of system-oriented ship construction and zone-oriented construction. With system-oriented methods the next step would be for the shipyard designers to develop detailed drawings and material lists for every system showing all of the information about that system throughout the entire ship.

In zone-oriented construction, the next step taken by shipyard designers is to segment the ship geographically into zones and to develop detailed drawing and material lists for installation of all equipment or system components which are to be installed. Using ground rules set by the production planning department, the designer also identifies, on installation drawings and material lists, the stage of construction at which each work task will be undertaken. Every task of ship construction is thus identified by zone and stage. Parts, materials, and work instructions are then sequenced and coded accordingly.

The degree to which the designer can accomplish all this depends on the extent of his knowledge of the construction sequence. Any lack of integration or communication between the designer and the production department is extremely disruptive. To define how each unit is to be fabricated, the traditional functions of design and production must now be integrated. The designer cannot guess how the ship will be built; he must know. Continued interaction among engineering, planning, and production personnel is essential to define how each unit is to be fabricated, installed, painted, and so forth.

INTEGRATION OF ENGINEERING AND PRODUCTION FUNCTIONS AND APPLICATION OF ZONE-ORIENTED SHIP CONSTRUCTION METHODS IN THE UNITED STATES

U.S. naval shipbuilders implement various production processes which, in most cases, are unique to their facilities and the types of ships under construction. Within this heterogeneous industrial environment, productivity increases are enabled through simultaneous consideration of design, planning, and production factors at an early stage.

In the early 1970s, as a result of losing many competitive shipbuilding awards for commercial ships to overseas shipyards, a number of U.S. shipbuilding executives visited Japanese and European shipyards to investigate the technical reasons for their success. The visits precipitated much discussion about Japanese shipbuilding methods in the United States. The National Shipbuilding Research Program (NSRP) investigations cited previously were begun in 1976, with the objective of making the Japanese advances accessible to U.S. shipbuilders.

Today, every major U.S. shipbuilder, including all naval shipbuilders listed in Table 1, is integrating its engineering and production functions and is employing zone-oriented ship construction methods to some extent (or is planning to). Very probably, each shipbuilder would accelerate the transition with new shipbuilding opportunities. Zone-oriented techniques are also being applied to naval ship overhauls (n.a., 1984).

The NSRP has been, and continues to be, a catalyst for the introduction and application of zone-oriented ship construction methods. Where the methods have been applied to naval construction, the cooperation and support of the Navy, and complementary changes in Navy procedures, have been instrumental and necessary. For their part, shipbuilders are accomplishing the transition incrementally, over several ship construction efforts.

PRODUCTIVITY IMPROVEMENTS

With system-oriented techniques, the detail design and installation of many systems and components may be delayed until late in the construction process. Since there is not much pressure to complete engineering or procurement until just prior to installation, significant problems may turn up late and result in added difficulty and cost.

Zone-oriented methods require additional engineering rigor. With zone-oriented methods, system details are defined earlier. Production planners are required to specify exactly where the unit breaks are to be, and what stage of production each piece of each system will be installed. These factors influence the locations of joints and fittings. Material lists define where material is to be delivered for installation. The additional engineering effort may lengthen the engineering schedule, but ship design and planning will be as complete as possible before production begins. This leads to considerably shorter construction times because:

- o Work items are more completely identified and sequenced. For example, since the routing of each piping system is known, pipe penetrations can be cut out of bulkheads at the time that bulkheads are cut from plate steel. This is much more efficient than erecting staging, laying out the hole, and then cutting the hole by hand after the bulkhead has been erected.
- o Material and equipment needs are identified earlier. This enables earlier ordering and availability of information concerning the equipment; greater assurance of on-time delivery of material; and, more extensive assembling of materials at staging areas into work packages.
- o Earlier and more complete engineering definition of the ship gives the Navy a head start on spare parts identification and ordering, and other logistics as well as training support.

Direct improvement in the productivity of construction methods result from the following, which are characteristic of zone-oriented methods:

- o Similar tasks are accomplished at specifically designed and dedicated locations.
- o Shipyard workers specialize to a greater extent. More personnel work at a single site, with ready access to material and equipment. Less time is lost in setting up for work.
- o The work environment at the dedicated work sites is enhanced with better light and ventilation. Interference between tasks and trades is minimized through improved planning.
- o The production worker has easier access. Staging is kept to a minimum, thereby reducing set-up time, making work easier, and improving safety.
- o Material availability is improved. There are fewer waits for crane lifts, tools, and other materials.

As a result of these improvements, the man-hours for a given amount of work are reduced, schedule durations are reduced, and quality and safety are improved. Figure 6 compares the schedule and man-hour distribution of Bath's FFG program (zone-oriented construction methods) with its earlier DEG progam (system-oriented techniques). The ships are comparable in terms of size and mission; however, the FFG is a considerably more complex ship, on account of more advanced electronics. Both ships were acquired in production runds of 5-6. The outstanding difference, highlighted by the figure, is in method of construction.

Zone-oriented methods also enhance safety and quality. Table 6 documents the significant improvements in quality performance that Bath experienced over the life of the FFG program, as it adopted zone-oriented construction methods.

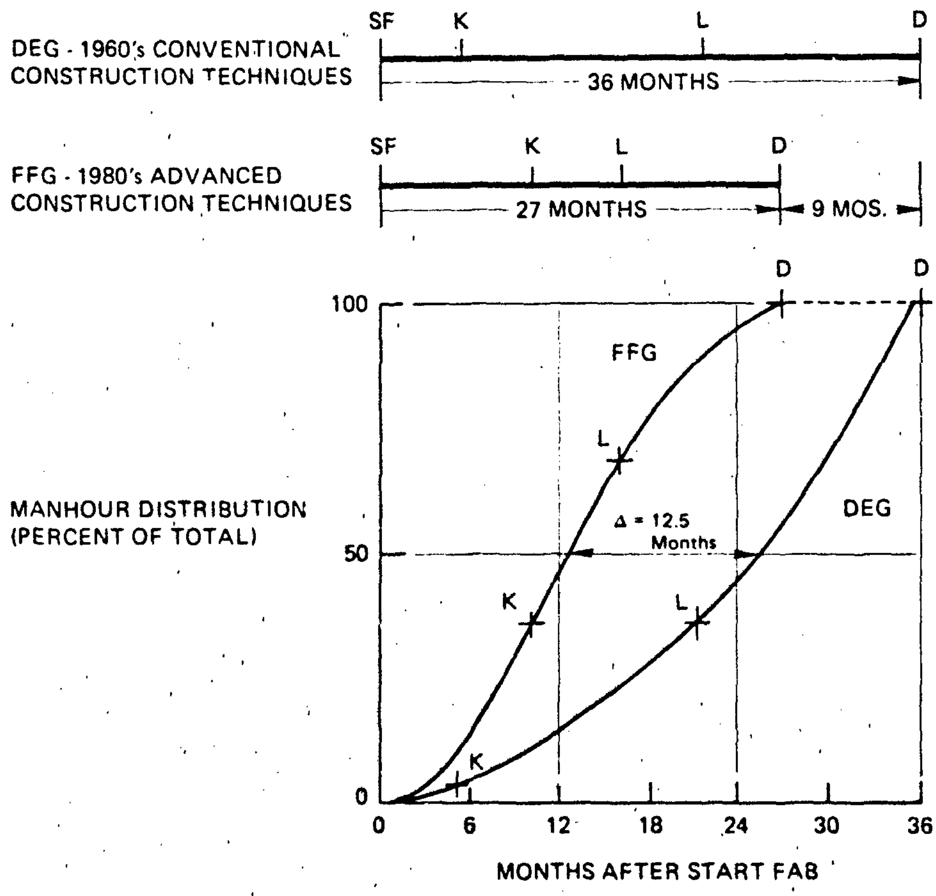


FIGURE 6 Comparison of naval construction program using production-oriented and systems oriented methods.

KEY: SF - Start fabrication
K - Lay keel
L - Launch
D - Delivery

TABLE 6 FFG 7 Program Quality Performance[a]

Ship	Unplanned Labor Percentage	Quality Deficiency Reports	Incomplete Compartments At Builder Sea Trials
FFG 7	7.4%	300+	50+
FFG 8[b]	2.5	158	39
FFG 11	2.2	80	22
FFG 13	1.6	49	1
FFG 15	0.8	25	1
FFG 16	0.8	27	0
FFG 21[b]	0.6	34	0
FFG 24	0.5	21	0
FFG 26	0.5	26	0
FFG 29	0.4	30	0
FFG 32	0.4	41	0
FFG 34	0.5	28	0
FFG 36[b]	0.6	57	0
FFG 39	0.5	55	1
FFG 42	0.5	23	0
FFG 45	0.5	33	0

[a]Improvements shown in table result from lessons learned from production as well as adoption of zone-oriented methods.
[b]Class design upgraded at this point.

SOURCE: Bath Iron Works.

A British study of zone-oriented ship construction concluded that the cost differential between building something in a shop, preassembling it on a unit in an erection area, installing it on a ship on the building ways, or installing it on a ship in the water, runs from 1 to 5 to 10 to 20, respectively (Easton, 1980). Simply stated, if the shipbuilder can preassemble a pipe run with valves and pipe and fittings in the pipe shop and test it in a shop and then install it as a unit, it would be assigned a labor cost factor of between 1 and 5. The same operation performed at dockside would be assigned a labor cost factor of 20. In actual practice in U.S. shipyards, the committee is aware of a number of instances where the labor hours of production have been halved or better as the result of the application of zone-oriented ship construction methods.

THE SHIPBUILDER AND THE INTEGRATION OF ENGINEERING AND PRODUCTION FUNCTIONS

Before the transformation described in the preceding chapter, engineering and production in U.S. shipbuilding were essentially segregated activities. Engineering designed the ship to specific performance requirements and described the finished product by means of engineering drawings and material lists. Production transformed these drawings and material lists into usable production documents and constructed the ship accordingly. This arbitrary division is contrary to the integrated engineering approach required to support zone-oriented design and construction techniques now being implemented by most U.S. shipbuilders. The experiences of leading shipyards who have implemented these techniques indicate that shipyard implementation of zone-oriented methods depends upon a high level of integration between engineering, planning, and production functions. The thrust of that integration is the development of an engineering function that understands the production process, incorporates production considerations starting early in the preliminary and contract stages of design, and develops zone-oriented construction documentation during the detail stages of design.

Management Understanding and Commitment

Zone-oriented ship design and construction methods have considerable impact upon the shipbuilder's organization in terms of changed processes, roles, and management style. Product-oriented work breakdown structures, modular construction techniques, and zone outfitting have organizational and managerial requirements which differ significantly from traditional practice. These differences include: the requirement for more organizational and process integration and discipline, an increased emphasis on earlier and more complete engineering and production planning, a shift in initial program emphasis from production to nonproduction activities, and a balanced emphasis on outfitting and structure.

For the integration of engineering and production to be successful, top management's full awareness, understanding, and appreciation of the zone-oriented approach are required. The impact will be felt in terms of significantly realigned production and nonproduction schedules, costs, procedures, priorities, and manpower skills. Changes of this magnitude require full understanding, commitment, and support from senior management. Any reluctance on the part of management could significantly reduce the total potential benefits or disrupt the operation of the organization.

At a lower level, experienced middle- and first-line managers and supervisors may perceive the changes as threatening because they will require people to perform unfamiliar tasks for which they will possibly have little or no training. Shipbuilders need to train their personnel in the technical and the human aspects of the new methods. The result will be the production of a superior product at lower cost with shorter overall schedules. This may lead to improved market position and more

business with an attendant increase in job opportunity and security for the work force. In summary, the essence of management's task is to recognize and understand the extent of change required and to establish an environment where all persons involved are comfortable with that change.

Organizational Changes

Zone-oriented ship design and construction methods require organizational changes that result in an extensive restructuring of the shipbuilder's operations. Traditional organizational structure, roles, work content and schedules, information format and flow, and procedures require realignment to suit the new approach.

Under the conventional systems approach, as shown in Figure 7, the shipbuilding process is characterized by lengthy and relatively independent yet parallel design, planning, and production processes. This overall approach, though appearing flexible, represents a costly approach to design and production as each functional area independently generates its output without adequate consideration for the synergistic effects of integration. Functional interfaces are poorly defined, little standardization of products or processes is achieved, product rework is extensive, and management control is limited.

Zone-oriented methods require an approach that integrates engineering with production, thus achieving significantly earlier and more precise engineering and planning execution. This integrated engineering and production approach is based upon the development of interim production products and a phased design process which produces production documentation that is organized spatially, and by stage of construction to support directly zone-oriented construction methods. Implementation of this phased design approach considerably improves management control and design quality. The thrust of the above changes is the refinement of the pre-production process to directly support zone-oriented construction methods, just as the more traditional system-oriented design process supported traditional, system-oriented construction methods.

As shown in Figure 7, these design phases, following preliminary design, include:

- Contract Design - finalization of overall operational requirements, critical system requirements, and ship specifications to support pricing and contracting; often performed by the Navy or at their direction. This phase results in the description of the ship as a complete system.
- Functional Design and Planning - development of functional and spatial requirements by mechanical, electrical, and hull system. Each system of the ship is defined.
- Transition Design and Planning - zone-oriented spatial optimization of the routing of the ships service distributive systems and initial detail construction planning. Information organized by system up to this point is reorganized by zone.

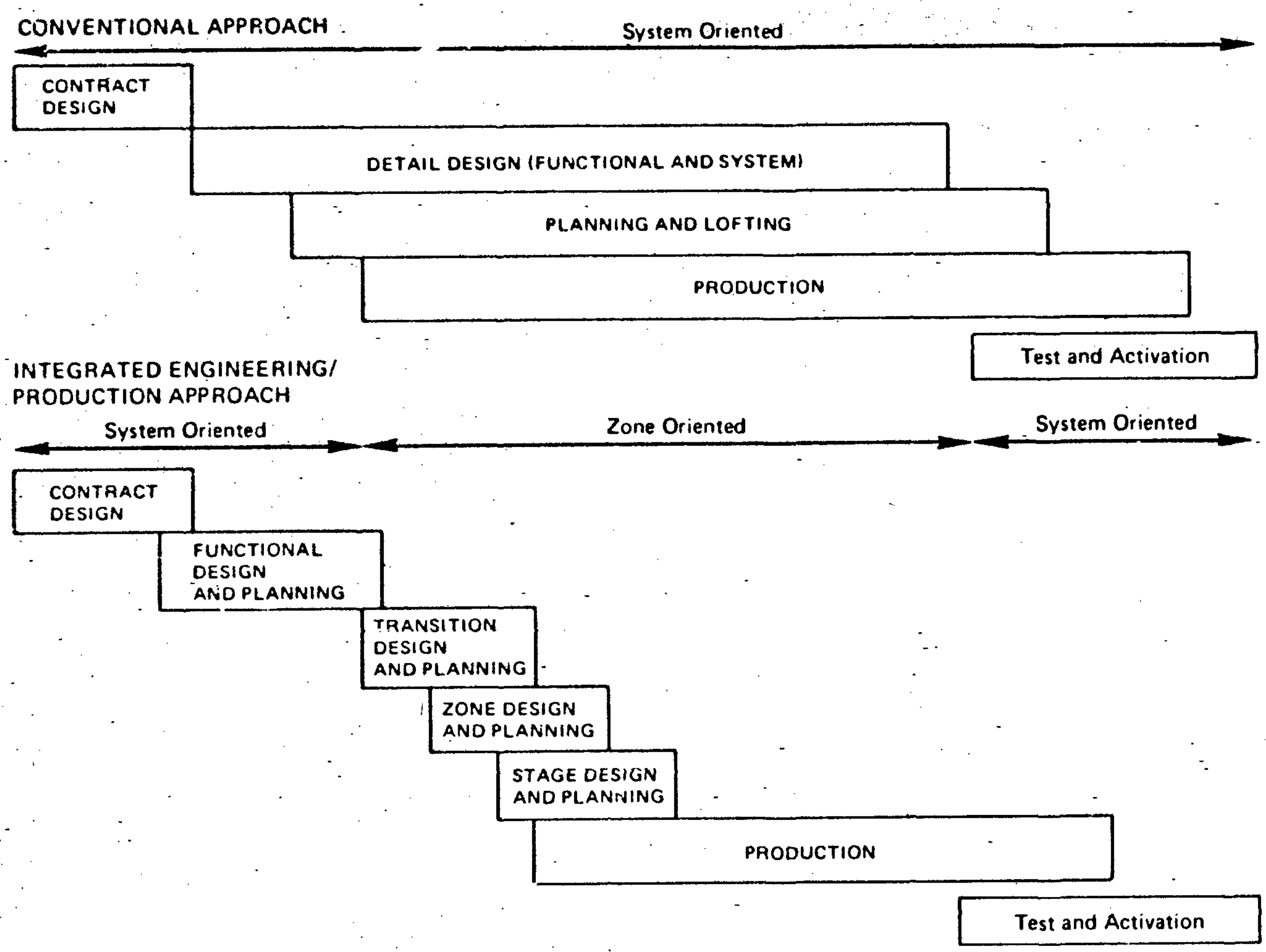


FIGURE 7 Integrated engineering/production approach.

- Zone Design and Planning - zone-oriented geometric definition and implementation of construction planning, including stage of construction considerations.
- Stage Design and Planning - detailed work instructions and construction planning implementation by zone and stage of production.

Where the shipbuilder has a strong in-house design capability, the zone and stage phases of design and planning may be combined. Where the breadth and depth of personnel training or capability is insufficient, it will likely make sense to retain these as two separate steps. When an outside design agent is involved, the shipbuilder may choose to retain primary responsibility for stage design and planning.

A more detailed comparison of these two approaches, as shown in Table 7, highlights additional differences. Under the integrated engineering approach, construction strategy and interim product definition are incorporated much earlier in the engineering process. Design, material definition, and construction planning move in a controlled, logical, and sequential fashion from the general to the specific. The timing of decisions is moved significantly earlier. Vendor-furnished and government-furnished information (VFI/GFI) is required earlier. Engineering, incorporating both planning and production considerations, focuses not only on the traditional final product definition but also on the development of zone-oriented documentation, which will directly support construction.

As engineering, planning, and production processes become more integrated and employ a zone-oriented approach, the structure of the shipbuilding organization will have to keep pace and change from a traditional functional structure to a matrix or zone-oriented structure. While the specific structure and rate of change will vary between shipyards, management must recognize this key issue and plan for smooth organizational transition. The use of joint engineering, planning, and production teams for production engineering is one example of a logical transition approach.

The greatest potential impact of the shipbuilder's implementation of an integrated engineering and production approach necessary for the adoption of zone-oriented construction techniques will be in the area of engineering and production schedules. To reduce the overall engineering schedule duration, equipment information (VFI and GFI) must be available earlier. Design, planning, material ordering, and production decisions must be made earlier and in a more interrelated fashion.

Closer integration of engineering and production also affects costs. Engineering must provide more information and greater detail in the documentation provided to production. While a rapid expansion of the engineering function could result in unanticipated cost increases, a well-managed implementation will lead to controlled, modest increases on the first ship of a class. Even if engineering costs were to increase up to 10 percent on the first ship, the experience of shipbuilders who have implemented these approaches indicates this cost is more than offset in reduced pre-production and production man-hours on the first ship. Additionally, significant

TABLE 7 Engineering Products by Phase of Design

SYSTEMS-ORIENTED CONSTRUCTION	ZONE-ORIENTED CONSTRUCTION
Functional Design	Functional Design
o Engineering analysis o Weight and stability control o Lines and offsets o Structural scantlings o Diagramatics - distributive systems o Arrangements - major spaces o Equipment and component list o Purchase specification - VFI/GFI	o Engineering analysis o Weight and stability control o Lines and offsets o Structural scantlings o Diagramatics - all systems o Arrangements - all spaces o Equipment and component list o Purchase specification - VFI/GFI o Material definition by system o Priority routing instructions o Construction standards o Material standards o Manufacturing drawings o Build strategy o Interim product definition (PWBS)
System Design	Transition Design
o Construction standards o Material standards o Detail arrangement drawings by system o Composite check for interference o Material definition by system o Limited manufacturing drawings o Test instructions by system	o Optimum system routing sketches (spatial) o Operational/maintainability considerations o Detail construction plan
	Zone Design
	o Detail composite arrangement by zone o Material definition by zone
Planning and Lofting	Stage Design
o Detail construction plan o Interim product definition o Structural lofting o Outfit fabrication documentation	o Detail construction drawing by zone/work type/stage o Material definition by interim product and stage (PWBS) o Structural lofting o Outfit fabrication documentation o Test instructions by system and test stage

savings are achieved in the areas of engineering and pre-production maintenance and production costs for all followships in a multi-ship procurement.

Communications

Effective communication involves the timely transfer of information in a usable format. Communications are enhanced when management establishes an environment that encourages open communications between all functions and levels within the organization. Improved communications also require properly defined interfaces, well-organized channels, and the availability of effective tools for communications. The integration of engineering and production, and the shorter schedules that result, place greater urgency on the need for early decision making and faster and more precise communications. On-going interaction among middle-management personnel of the design engineering, production planning, and production engineering organizations to consider and define the exact details of the most cost-effective sequence of hull construction and installation of equipment is needed, so that the documentation developed by engineering will effectively relate to that sequence.

While most large organizations are well organized for vertical communications, an integrated engineering and production approach also requires effective horizontal communications. The streamlining of horizontal communications between functions, while difficult, is mandatory if a well-integrated process is to be achieved. This integration requires the development of mutual technical and management understanding among functions, particularly engineering, planning, and production.

The long-term trend of this integration will require realignment or consolidation of selected engineering, planning, and production engineering functions. To assist in this transition, a number of tools are frequently employed to improve horizontal communications. First, cross-training and inter-departmental transfers aid the development of mutual technical and management understanding and the ability to communicate effectively (union concurrence may be a precondition for these advances). For example, the assignment of engineering personnel to production will increase the engineering department's knowledge of the production process and improve communications. Second, and closely related, is the use of joint engineering, planning, and production teams. Third, is the use of readily accessible computer-aided design and manufacturing (CAD/CAM) data bases structured to serve broad engineering, planning, and production needs as well as customer and lead/follow shipyard requirements. Fourth, the development and use of procedural, equipment and interface standards ease communications by documenting existing knowledge and experience, thus minimizing the need for exchange of technical information.

Design Agent/Shipbuilder Interface

The application of zone-oriented ship construction methods depends on a very high level of mutual knowledge and communication between the shipbuilder's designers and his production engineers and planners. Particularly important is a qualified production engineering capability to both devise and document production engineering. This interface requires particular attention when the shipyard uses an independent design agent.

For the design agent to participate fully, supervisors and working-level personnel must become knowledgeable in many aspects of the shipbuilder's construction strategy, manufacturing capabilities, and the preferred standard construction details. Additionally, co-location of design agent personnel and the shipbuilder's planning and production engineering personnel are mandatory to ensure effective integration. This can be accomplished at either the shipbuilder's or the design agent's facilities. Just as important, the design agent's scheduling group must work closely with the shipyard schedulers to develop and maintain mutually an integrated engineering, material procurement, VFI/GFI and production schedule.

This interface must be carefully cultivated during the transition period as shipbuilders implement the new construction techniques. The new techniques of planning work and, more importantly, presenting construction information to production workers means radical changes in drawing format and content. Virtually nothing produced by the design office will remain unaffected by the changes. The development of standards (i.e., engineering, materials, planning, and production) as communication tools provide a means of improving the design agent and shipbuilder interface during this transition.

The communication referred to must be constant and interactive. Where performance requirements run counter to design for producibility, the design engineer must be able to articulate the requirement to the production engineer in terms that permit resolution of their mutual problem, as opposed to dividing the problems into "theirs" and "ours." Mechanisms for encouraging communication include formal and informal information exchange, cross-training of a cadre of engineers from both design and production, utilization of a team approach, and extensive use of a computer-aided design data base both as a communication tool and as a means of preparing engineering documentation. The commitment of design and production planning management to intensive cooperation and improvement is crucial.

Follow Shipbuilder Support

Complete follow shipyard support by the lead shipyard can significantly contribute to overall Navy program effectiveness in both cost and schedule. From an overall program perspective, it is essential to transfer a comprehensive ship design and production support package to the follow shipbuilder.

In the transfer of a total support package, it is imperative that early, open, and complete communications be established between lead and follow shipbuilders. The more sophisticated engineering and production planning characteristic of zone-oriented methods makes lead yard/follow yard relationships both more difficult and more important than in the conventional approach. Unless facilities, suppliers, and production methods of both lead and follow yards are taken account of in contract design, the lead ship support data furnished to the follow shipbuilder will require extensive reworking. Furthermore, compromise in design to accommodate facilities, supplier, and production methods differences could result in designs that preclude either yard from obtaining maximum productivity.

Consideration for follow shipbuilder support should be addressed early in the contract and detail design stages. The follow shipbuilder should participate in lead ship decisions on producibility and design documentation. In terms of producibility, follow shipbuilder input to construction zones, design standards, and general material standards is required. These key areas are particularly important in view of the differences in construction techniques and capacities among shipyards. Equally important is the follow shipbuilder's input to decisions on drawing format, design zones, dimensioning, part numbering, and purchase specifications.

Effective follow shipbuilder support will result in overall program savings. Support from the lead shipyard in the form of understandable or readily modifiable design, planning, material, and production documentation will positively enhance both follow shipbuilder performance and total Navy program costs and schedules through the reduced need for information redevelopment.

Table 8 outlines the characteristics of an improved follow shipbuilder package designed to support zone-oriented ship construction methods. Of particular note are: the increased documentation in terms of engineering data, material definition, and construction planning; the use of computerized data transfer; and the expanded sustaining support activities.

In view of the increased emphasis on improved software products and non-production activities necessary with zone-oriented construction methods, particular care in the development and execution of an effective follow shipyard support plan is mandatory. The entire Navy, lead shipbuilder and follow shipbuilder relationship requires early and precise definition prior to the commencement of lead ship detail design.

Education and Training

The transition from systems-oriented to zone-oriented shipbuilding methods requires development of technical, professional, and managerial skills to cope with the integration of previously segregated functional skills, more precise information, improved technical understanding, and greater facility in dealing with earlier decision making. It will impact the education and training needs of those who acquire or build ships including senior Navy and shipbuilder management, middle-level

TABLE 8 Follow Shipbuilder Support

CONVENTIONAL	INTEGRATED ENGINEERING/ PRODUCTION APPROACH
Documentation	Documentation
o Engineering analysis o Purchase specifications - VGI/GFI o Functional design drawings o Detail design drawings and material lists o System operating manuals, logistics and configuration management documentation o Selected lofting and outfit fabrication documentation (lead ship only) o Selected construction planning (lead ship only)	o Engineering analysis o Purchase specifications - VFI/GFI o Functional design drawings o Detail transition, zone and stage design drawings and material lists defining both purchase material and in-process control of interim parts/assemblies o System operating manuals, logistics and configuration management documentation o Structural lofting and outfit fabrication documentation o Conceptual/detail construction planning o Construction standards
Management and Computer Systems	Management and Computer Systems
	o Material catalog o Computerized material/labor/ engineering/planning systems (to extent required) o Digital transfer of engineering/material/planning data
Support Activities	Support Activities
o Lead/follow shipbuilder liaison offices o Participation in key technical/ planning meetings o Assistance in resolving engineering, planning, and material liaison requests	o Lead/follow shipbuilder liaison offices o Participatioon in key technical/planning meetings o Participation in producibility and design documentation decisions o Assistance in resolving engineering planning, and material liaison requests o Training of follow yard personnel on lead yard technical planning, material procurement and production procedures (to extent required)

Navy and shipbuilder management, first-line supervision and the general work force, and students of naval engineering and shipbuilding management.

One possible approach to the education and training needed for the transition to an integrated ship design and production process is shown in Table 9. The detailed implementation may vary in accordance with individual shipyard situations. The first objective is to develop awareness and understanding of the approach and management requirements. The second is to impart the technical and managerial skills required.

For senior management to provide overall direction and control in the transition, a broad understanding of zone-oriented concepts and key technical issues will be required. Middle management will also require an awareness of these concepts, as well as a more detailed knowledge. The work force itself needs to understand the new direction in shipbuilding and how current methods will be affected.

The need for improved education and training at the engineering and management student level is a particularly important issue in the transition to more modern ship design and construction. The newer methods of ship production require a constant supply of college-educated ship production engineers who can deal analytically with the industrial engineering aspects of shipbuilding, including statistical control of manufacturing and group technology. Students need an overview of the new technology to fulfill their future management role. To accomplish this, current naval architecture and marine engineering curricula should be expanded to provide sensitivity to zone-oriented ship design and construction processes. Shipbuilders also need to take students for periods of time on a cooperative basis. The universities, with Navy encouragement, are beginning to address the need for education in ship production.

The recent efforts of the Society of Naval Architects and Marine Engineers' (SNAME) Ship Production Committee, SP-9 Panel on Education, represent an important and increasingly effective industry approach to the industry's educational needs. The Navy and the individual shipbuilder must also work to address their individual needs by implementing in-house programs for technical and managerial development.

THE NAVY AND THE INTEGRATION OF ENGINEERING AND PRODUCTION FUNCTIONS

The adoption by shipyards of zone-oriented ship construction methods, and the coincident closer integration of shipbuilding engineering and production functions will affect many Navy activities. Understanding these changes will enable the Navy to take advantage of them in ship design, acquisition, and operation.

Navy Management Commitment

It is a truism in management circles that any substantial change desired in an organization must have the support of top management to succeed. It is less often stated specifically that top management must understand and agree with the change and its implications before the

TABLE 9 Integration of Engineering/Production Education and Training

Target Group	Objectives	Approach
Senior Management	Awareness and broad understanding of approach and management requirements, including management commitment and recognition of need to manage a transition.	Two-day seminar on key technical and managerial issues: o Organizational development concepts; o Group technology; o Product work breakdown structure (PWBS) o Integrated hull construction, outfitting, painting; o Design for zone outfitting; o Employee training; o Statistical control of manufacturing; o Impact of standards. o Computerized management systems.
Middle Management (including functional department heads)	Awareness and technical understanding of the broad range of functional areas affected by the implementation of the modern integrated shipbuilding process, including advantages and technical aspects of a zone-oriented building strategy. Enable naval officers to manage Navy interests in a zone-oriented shipbuilding effort.	Ten-week continuing education course covering specific technical and managerial subjects outlined above - conducted on a shipyard or regional basis.
First Line Supervison and Work Force	Awareness and detailed technical skills in the area of changing engineering and production functions, including the reading of statistical charts describing how work processes are performed, and training in related analysis techniques.	Expanded in-house shipyard training and apprentice programs to include training in functional skills, shop management, quality control, and statistical control of accuracy.
Students (engineering and management)	Awareness and increased sensitivity to the non-engineering aspects of the modern shipbuilding process. Create a pool of people qualified to develop into the dual role of	Expand current engineering curricula to include exposure to modern, zone-oriented shipbuilding systems and management.

necessary commitment to support the change can be expected. Integrating engineering and production functions necessitates many changes in the way naval ships are designed and built, and requires many changes in the overall Navy organization which performs these functions.

It is considered that definite steps must be taken to ensure an enhanced awareness and understanding, at all levels of Navy management, of the type and degree of changes to the shipbuilding process that are being made by U.S. shipbuilders, and the implications that these changes have on existing scheduling, organization, management, and contracting procedures of the government. Identification of a dedicated organizational element within the Naval Sea Systems Command (NAVSEA) organization for reviewing new ship construction methodologies and their implications to the ship acquisition process should be considered. Visits by such a group to various shipyards which are implementing zone-oriented ship construction methods, combined with discussions of the beneficial impact of doing design engineering with foreknowledge of plans for construction would be a good start. A necessary next step is an appreciation of the changes to Navy schedules, organizational practices, and procedures, which are required to attain the benefits. A course for middle and senior managers at the NAVSEA Institute could increase the state of knowledge of zone-oriented construction within NAVSEA.

These changes must be considered in the context of NAVSEA organizations, including supervisors of shipbuilding (Supship) and will cover aspects ranging from basic acquisition strategies to quality assurance and final documentation of the ship design. Understanding these changes will require discussions with working and management level people throughout the Navy engineering community.

The advantages to the Navy in the form of more and better ships per dollar expended and per unit of calendar time are very real and clearly demonstrated by what has already been accomplished in U.S. shipyards by only partial implementation of the methods suggested. Understanding these advantages and the changes required to achieve them will lead to the essential commitment by Navy management.

Effects on Schedule

The implementation of zone-oriented construction methods and the coincident integration of engineering and production by shipbuilders will significantly benefit both Navy and shipbuilder schedules. This integration will require schedule realignments that move engineering and design work earlier and production work later on lead ships, and drastically reduce construction durations on follow ships.

For the Navy to gain full advantage of this new method of ship design and construction, Navy program schedules should support the accelerated information and decision-making requirements inherent in this approach. Schedule impacts include budgeting in multi-year programs, leadship design, GFI and Government Furnished Equipment (GFE), crew availability, logistics support, follow ship production support, and change schedules.

While information must be available earlier for lead ships, material receipt dates may be delayed relative to the timing required by conventional shipbuilding techniques. Full and complete contract design is required and must incorporate early product performance decisions and early GFI. Design budgeting and ultimately combat systems interface standards are vehicles which significantly assist in satisfying the early information requirement.

While the new approach to shipbuilding may require a schedule allowance for a longer than traditional lead ship design duration prior to the start of construction, the higher level of completeness in the design and production engineering permit a reduction in the production schedules on both lead and, more markedly, follow ships. Accordingly, GFE delivery for follow ship production must be accelerated to suit both reduced overall construction time and earlier installation. As a result of more fully defined and developed design and production documentation allowing more effective production work, follow ship deliveries may occur 6-18 months earlier, requiring equipment deliveries to be accelerated in some cases by as much as 24 months.

Effects on Navy Decision Making

Full integration of engineering and production requires a far more structured and disciplined approach to shipbuilding than past practice allows. In the past, particularly during lead ship design and construction, a great deal of production activity was accomplished on the basis of doing as much as could be done in an area based on the information available and then returning later to complete the job. This frequently required reworking completed items and was therefore doubly inefficient. The idea of zone-oriented construction is to start with complete knowledge of what is to be done, to schedule the work to minimize revisiting an area to complete work, and to eliminate undoing or repeating anything which has been done.

The requirement for earlier information and the detailed scheduling of the various steps in the construction process based on using that information for both design engineering and production planning mean that delayed decisions have a very substantial adverse effect. In the traditional environment a delay in receipt of information describing a piece of GFE is disruptive, but the information gap can usually be "worked around" in the hope (not always fulfilled) that any rework required will be local in nature. With full integration of production planning with design engineering, missing information in the design has a greater effect. It inhibits material procurement, outfit planning, and ship fabrication, and leads to rework. These impacts are, of course, always present but are harder to see in the traditional planning environment.

The Navy's decision making will be affected first in the development of the Ship Acquisition Plan (SAP). Full integration of engineering and production implies production input during preliminary and contract design. This has been Navy practice with increasing emphasis since 1965 and is receiving strong emphasis in the current DDG 51 Program. The SAP must make provisions for selection of prospective shipbuilders early to allow zone-oriented input both in the design phase and in establishing schedules and milestones for the detail design and construction program.

During contract design and detail design, timely Navy decisions on equipment selections, design trade-offs, and potential design changes will be essential to gain the advantages of the new construction techniques. The Navy's current organization, using Ship Acquisition Project Managers (SHAPMs) with decision-making authority is an effective vehicle. Present levels of manning and expertise in the SHAPM organizations may need bolstering to improve reaction time. SHAPM liaison with and influence over Participating Managers Acquisition Requirements (PARMs) also needs to be strong to ensure responsiveness to the more rigorous project schedule.

Achievement of engineering and production integration will affect Navy decision making by requiring a firmer design baseline of the ship when released at contract design and by recognizing that the detail design by the shipyard will require earlier completion of diagrammatics and decisions on Vendor Furnished Equipment (VFE). This firmer design may present a problem with surface combatants because the combat systems to be installed usually require development during contract and early detail design, so that they will carry the latest technology to sea to provide the battle group with capabilities that are superior to those of potential adversaries. However, this obstacle can be lessened with combat system interface standards (see subsequent discussion).

Effects on Shipbuilding Contract Package

Integration of engineering and production implies a need for changes in contract requirements, terms, and supporting technical documentation. Changes in contract requirements include changes in deliverables which must be considered for each shipyard involved (see Table 10).

TABLE 10 Contract Design Package Schedule of Deliverables

<u>SCHEDULE A</u> -	Delivery of government-furnished material (GFM) and government-furnished equipment (GFE)
<u>SCHEDULE B</u> -	Delivery of vendor engineering services for GFE
<u>SCHEDULE C</u> -	Delivery of GFI: special deliverables from the government as had been indicated by the RFP. This is a special document for the documentation usually referenced in ship specifications.
<u>SCHEDULE D</u> -	List of government-furnished installation and test support equipment
<u>SCHEDULE E</u> -	Plan to develop the list of government-furnished platform installation and checkout spares
SCHEDULE F -	Design budgets for interface mangement during initial detail design
<u>SCHEDULE G</u> -	Ship systems engineering standards for variable payload ship features

Certainly, the impact of requiring earlier GFI delivery (or interface standards by zone) and possibly later GFE delivery for the lead ship caused by zone outfitting must be factored into the schedules for deliverables. For developmental systems on surface combatants, this may be difficult (unless zone budgeting or zone standards are used).

Changes in supporting technical documentation will include the design modifications incorporated in the contract design package as a result of production planning input and rescheduling of GFI to supply critical interface information as needed during the lead ship detail-design period. The traditional contract design package is intended to permit accurate pricing and to define the desired performance of the various subsystems. A better understanding by the Navy of the early phases of detail design as it will be practiced under the new engineering and construction methods could result in shifts in emphasis during contract design which would enhance the total process.

The functional aspects of ship design, which are whole-ship oriented and develop each system to the level required for detailed geographic consideration, are partly performed during contract design and partly during detail design. Table 11 delineates that portion of the functional design, which is ordinarily undertaken by the Navy. It appears from the table that greater emphasis on systems design and selection of equipment, with a reduction in level of detail in structural design and arrangements work, would create a better match between Navy design definition and shipbuilder requirements.

In combatant ships, operational needs dictate high manning levels and extensive man-machine interaction in some compartments. Necessary man-machine interface criteria must be met between displays/controls and personnel and between different systems which must work together to achieve mission success. This results in a set of contract documents that include many "non-deviation" or contract drawings, to which the shipbuilder is required to adhere unless a contract change is processed (see Table 12).

When contract drawings are used by the Navy, it is important that production considerations be taken into account early to reflect and take advantage of zone-oriented construction methods. Even "composite" drawings showing, for example, distributive systems for congested zones might be appropriate, before specifying an arrangement of an operational space in a contract design package. Clearly, the number of contract drawings should be minimized.

To the extent production considerations are not represented in the development of the contract drawings, the shipbuilder may be placed in a position of having to meet overall contract requirements that are in conflict with the specific requirements contained in the contract drawings. An alternative for the Navy is the use of contract guidance drawings, which describe an acceptable way of meeting the system design, without the requirement that the designer or shipbuilder follow all details of the drawing.

TABLE 11 Functional Design: Relationship Between Navy Contract Design and Shipbuilder's Detail Design

Functional Requirements	Navy Contract Design	Shipbuilder's Detail Design
o Develop primary structure scantlings	Scantlings done by Navy	Recheck all scantlings - occasionally optimize or modify due to development of equipment foundations and production considerations
o Develop arrangements	Develop arrangements. Some spaces developed as contract drawings	Often rearranged, sometimes extensively to suit final system design, GFI, and to allow improvements in productivity with no degradation of operability or maintainability
o Develop diagrams of distributive systems	Navy usually does only major systems	Must develop all
o Develop purchase specifications for purchased equipment	Navy specifies some characteristics for some equipment	Must develop for all CFE, and check all GFE
o Develop list of material	Develop list of GFE only	Develop lists of all material

TABLE 12 Contract Drawings for a Destroyer

General Arrangements - Inboard Profile
General Arrangements - Main Deck and Below
General Arrangements - 01 Level and Above
Topside Configuration
Molded Lines and Table Offsets
Displacement and Other Curves or Form
Midship Section
Machinery Arrangement Drawing
Radar Systems and Electronic Countermeasures
Gun, Torpedo and Missile Weapon System
Command Control & Display System
Underwater Surveillance & Acoustic Countermeasures
Radar Rooms 1 & 2 - Arrangement of Equipment
CSER #1 - Sonar Control Room - Arrangement of Equipment
CSER #2 - Arrangement of Equipment
CSER #3 - Arrangement of Equipment
CIC - Arrangement of Equipment
Sonar Equipment Room 1 - Arrangement of Equipment
Sonar Equipment Room 2 - Arrangement of Equipment
Sonar Equipment Room 3 - Arrangement of Equipment
Pilot House & Bridge Wing - Arrangement of Equipment
Signal Shelter & Signal Platform (P/S) - Arrangement of Equipment
C/S Maintenance Central Technical Library & Repair 8 - Arrangement of Equipment
Chart Room - Arrangement of Equipment
Power Supply/Conversion Room - Arrangement of Equipment
Navigation System and Ship Interfaces
Voice Interior Communications Systems
Alarm & Indicating Systems
Ship Control Console System
Shipboard Data Multiplex System & Ship Interfaces
Ship Entertainment and Training System
Interior Communications Switchboard Interties (TBD)
IC and Gyro Room No. 1 Arrangement
IC and Gyro Room No. 2 Arrangement
Radio Communication System Block Diagram
Communications Center Arrangement of Equipment

Combat System Interface Standards

To accommodate the shipyard's need for early information and the combat system designer's need for additional design time, a system of interface standards is under development. Combat system interface standards cover both capacity requirements for ship spaces containing combat system equipment and configuration requirements for the equipment to ship interface. Early efforts by the Navy to set aside or "budget" a

combat system zone within the ship while allowing flexibility in the specific equipment and arrangements within the zone occurred on the CG 47 Class (1978) and were called design budgeting.

Since 1980, the Navy has been developing ship/combat system interface standards for surface combatants under a program called Ship Systems Engineering Standards (SSES). Under the SSES approach, interface standards are used for both the combat system functional elements and the various ship spaces (also called zones) into which these systems are installed. These spaces may or may not be the same as zones defined by the shipbuilder during detail design for the purpose of ship construction. By designing and constructing the ship in these areas to the SSES, sufficient space, structural support and support services will be provided for the combat system equipment located therein.

A key to this concept, however, is that the standards will also control the combat system side of the interface--not only for a specific piece of combat equipment but any alternate equipment that could provide the same function (e.g., a missle or gun is interchangeable in a weapons zone). In addition, modernized upgraded equipment would be built to the same interface standards so that construction changes to later ships in a class would be minimized. This approach results in much of the combat system equipment being packaged into modules.

The combat system interface standards being developed under the SSES for both ship and equipment are shown in Figure 8. A ship which uses all these standards is called a Variable Payload Ship.

The center of Figure 9 indicates major interfaces between ship spaces and equipment that are subject to Ship Systems Engineering Standards. Characteristics shown in the outer circle in the figure are requirements that are normally imposed on the ship design or the combat system design and are not affected by the variable payload design approach. Allocation of combat systems to various ship spaces is accomplished by selecting types and quantities of combat systems spaces for each Variable Payload Ship size, and assigning combat system functions to each space. Capacity standards ensure that space, weight, and support services capability of these defined spaces of the ship are adequate for the assigned modules. Configuration standards ensure dimensional limits of shape, interrelationship of constituent parts, and patterns (such as those for bolting and cable connectors) of interchangeable combat system modules will fit and can be easily installed or removed.

The significance of this program and resulting interface standards for combat systems is two-fold. Their original purpose was to facilitate the changing or modernizing of weapons systems over the life of the ship. However, ship system engineering standards also facilitate ship construction by enabling zone-oriented ship design and construction to proceed prior to completion of specific combat system equipment design. Since Navy surface combatants are always using new (and sometimes developmental) combat systems, the need for GFI can be met at the level of the defined ship space for combat systems by means of the SSES. Sizing of distributive systems can then proceed. Under the SSES approach, access routes will be provided in the ship to permit

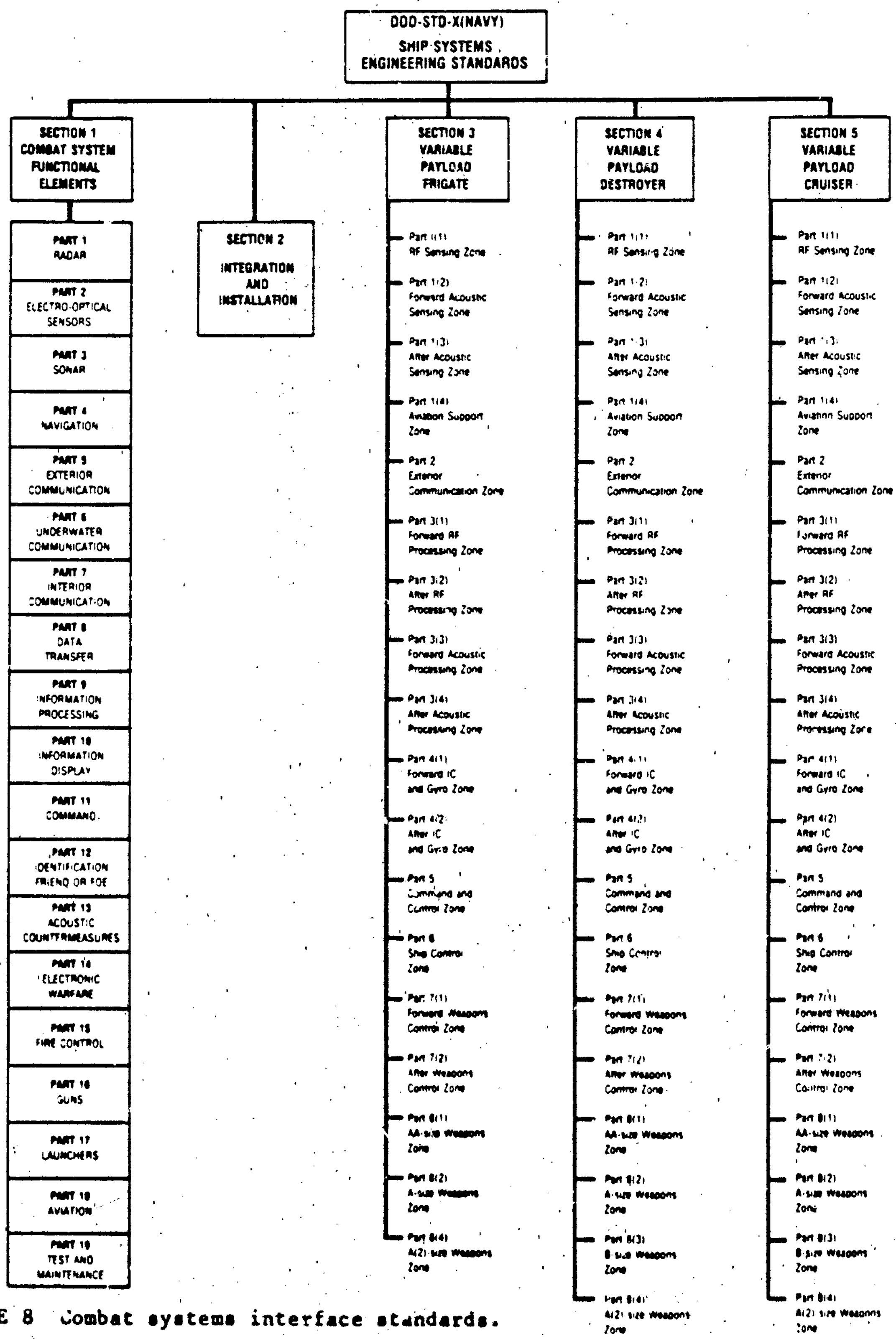


FIGURE 8 Combat systems interface standards.

SOURCE: U.S. Navy.

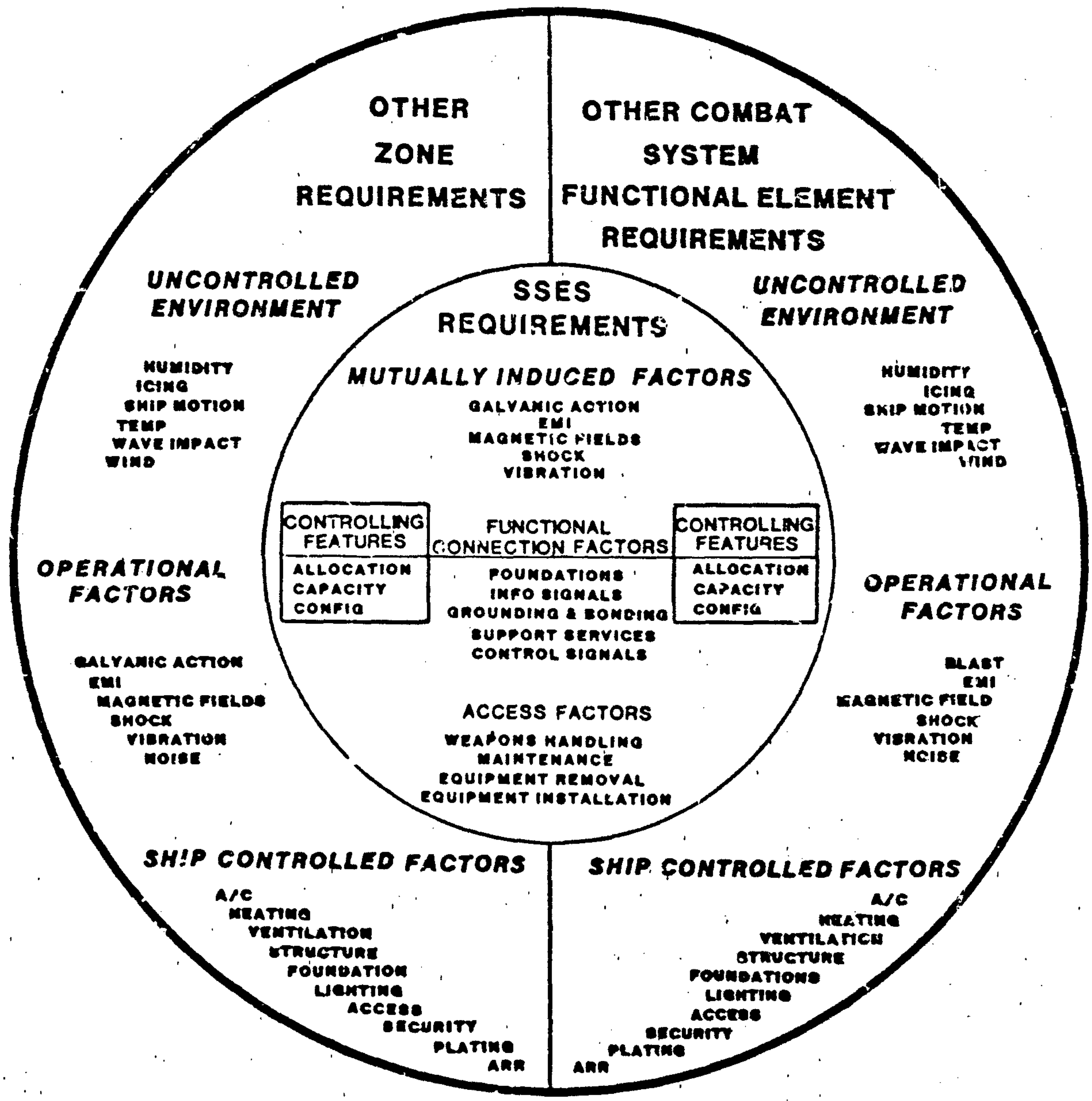


FIGURE 9 Major requirements for ship systems engineering standards.

SOURCE: U.S. Navy.

installation of all combat system equipment after completion of hull construction and outfitting. The ship can be built to the SSES and then "closed out" until the combat systems are ready for installation.

Changing Navy Requirements

Engineering changes are inevitable in the multi-year life of a Navy ship acquisition program. Improvement in mission performance, results of testing subsystems, and changes in priorities are but a few examples of why changes in the design and construction of Navy ships will continue to happen, and are desirable.

The number of changes and deviations in shipbuilding is typically large. For example, on a new class of Navy destroyers, 2,681 major (Class I) changes were generated by or imposed on the shipbuilder. Each of these changes affected a number of activities, including engineering, production planning, production, and material procurement, and required re-sizing of distributive systems, weight changes leading to structural changes and arrangements modifications, and other engineering changes.

To compensate for changes and attendant delays, shipbuilders and suppliers work around change or problem areas. This strategy adds to project cost because it is necessary to reenter areas that would otherwise have been completed during initial construction.

Elimination of changes is neither realistic nor desirable. All parties, however, share an interest in minimizing the number of changes, and in developing more efficient procedures for managing them. Zone-oriented techniques are especially useful in accommodating changes because they enable more precise understanding of the cost and schedule impacts of proposed design changes.

Action Required of the Navy

Through plans, budgets, schedules and procedures, the Navy establishes the major program milestones and time frame for ship procurement. As the shipbuilder integrates engineering and production functions to support zone-oriented construction methods, the Navy can assist by a complementary integration of its functions with the shipbuilder's process. The essence of the Navy task involves earlier and more complete planning and decision making. For the Navy, this will require a fuller understanding and capability to deal with a significantly different ship design and construction process.

It is necessary that the Navy recognize this need and develop an acquisition strategy that supports earlier and more complete planning and decision making. This requires a highly participative strategy that allows early lead and follow shipyard input to planning and contract design and one that will support early integration of the "Design for Production" concept into the preproduction process.

In consideration of overall program performance, Navy planning and acquisition strategy needs to take into account the relationship

between lead and follow shipyards. Detailed pre-planning of the lead/follow shipbuilder relationship should become routine practice. Contractual arrangements that accommodate early follow shipbuilder input and provide for more complete follow shipbuilder support will improve the Navy's overall program performance. Follow shipbuilders should have early input to the development of information formats and schedules and receive, in addition to the traditional drawing support, planning and in-process material information support that is computer transferable.

Concurrently, the Navy has to integrate the planning of SHAPMs and PARMs to reflect the changed GFI and GFM schedule requirements of zone-oriented methods, including phased submittals. Since accelerated engineering and design work and delayed production work will be characteristic of the new approach on a lead ship, implementation of revised funding schedules for design and material procurement will be required. Phased issue of GFI should also be implemented so that the shipbuilder may be provided with information which is available at the earliest possible time, without waiting for a completed package. In a followship situation, advanced procurement of long lead material may be necessary to achieve the compressed followship construction schedules.

Navy Technical Documentation Requirements

The documentation of a ship design in the form of drawings and other documents has developed historically over a period of many years. The typical drawing represents all or part of some system and provides information required by all of the people potentially interested in that system. These include: other designers whose systems must function with or avoid interferences with the depicted system; design quality reviewers who must verify the technical adequacy of the system; personnel who must purchase material to make the system; shipyard personnel who must fabricate parts of the system; shipyard personnel (generally different from the preceding group) who must install the fabricated and purchased pieces; still other shipyard personnel who must test the system; Navy ship's force who must operate and maintain the system; Navy and commercial shipyard designers, workers, and testers who must overhaul, repair, or modify the system during the life of the ship; and designers of later classes of ships who use the documentation as an example of successful or unsuccessful past practice.

Zone-oriented ship construction methods require and result in radically different design documentation. The documentation is geographically or zone oriented by construction process rather than by functional system. Perhaps the simplest example is piping. For zone outfitting, the ideal documentation is a single drawing showing all the piping to be installed in an area of the ship at a given stage in the outfitting process and containing only the information needed by the people doing the installing. The documentation used in system-oriented construction will usually consist of a set of drawings, one for each

piping system, each covering a much larger area than the one of interest, and each providing so much information extraneous to the task or stage of construction at hand that the information really needed is hard to find.

Most of the information now provided on shipbuilding engineering drawings is needed by somebody at sometime. Before undertaking the major change which is so desirable to improve the construction process, careful thought must be given to ensuring that the information needs of all the constituencies mentioned are met economically. An obvious first step is to canvass the constituencies to determine what their real needs are. Since the present formats have developed over time, it is to be expected that some of the information included is, or could be, available in some other form or may, in fact, not be needed at all. One means of addressing the design documentation requirements would be to provide comprehensive functional drawings, or diagrams, on all systems along with zone installation drawings incorporating a coded cross reference of systems. This type of design documentation has already been accepted by the Navy from several U.S. shipbuilders on recent contracts.

Maintenance Considerations in Design

When production engineering is integrated into zone-oriented design, shipboard equipment, particularly machinery components, are often arranged in functional groupings to permit piping connections to be made and tested at one time, and also for the equipment to be installed as a package on a partially complete portion of the ship. As in all arrangements of shipboard equipment, it is essential that design discipline be exercised to ensure spatial accommodations for equipment maintenance, repair, and removal.

SUPPLIERS AND THE INTEGRATION OF PRODUCTION FUNCTIONS

The changes being employed by virtually every naval shipbuilder to employ to at least some extent zone-oriented ship design and construction methods directly affect the supplier because they affect the shipbuilding schedule, and the shipbuilder's information requirements.

Engineering and Production Information

As has been explained, zone-oriented ship construction methods entail both more extensive and earlier engineering and design work on lead ships, with production coming later. On follow ships, the duration of construction is significantly reduced. For the supplier, this means that the shipbuilder needs engineering data in greater detail and sooner than before. Furthermore, the shipbuilder will be less tolerant of delays in or deviations from the supplier's production schedule because the "window" for the installation of the supplier's equipment

will be smaller and the consequences of any rework necessitated by contractor slippage will be greater.

Suppliers of major items, particularly those that are tailor-made for a particular ship, have to accept that early information is mandatory in the planning of zone-oriented construction. The traditional work-around schedules create a costly delay and also negate the benefits expected to be gained from the extra engineering and planning work.

The shipbuilder, Navy, and the supplier have to cooperate to assure a high level of awareness and commitment to the support of early information requirements. The need for cooperative development of early detail schedules should be reflected in a suitable contractual arrangement to give all concerned an incentive to succeed.

The need for earlier information and changes in the sequence of material definition may require some modification to Navy acquisition procedures. In the future, shipbuilder and supplier involvement may become a major supplier selection criterion since zone-oriented construction is based on strict schedule discipline. The Navy may also elect in the future to furnish more equipment that has in the past been contractor-furnished, to firm up design information in time to support detail design.

Standards can also improve design discipline and production support. In an attempt to standardize suppliers' engineering data in support of zone-oriented construction, at least one shipbuilder has compiled a computerized library of readily available vendor-furnished information and established working relationships with suppliers to maintain current information. The library includes engineering information on equipment used by U.S. shipbuilders in earlier and current naval construction programs. The savings afforded by the use of standard comp[illegible]s, engineering data for which is maintained by the shipbuilder, [illegible]parent from the streamlining evident in Figure 10.

Interface standards, described in the preceding section, offer a means of accommodating the shipbuilder's need for early information for modular construction and zone outfitting and the combat system designer's need for additional design time on Navy combatants.

Navy Acquisition Managers

The Naval Sea Systems Command (NAVSEA) is responsible to the Chief of Naval Material for the technical management of all ship acquisition programs.

In carrying out these responsibilities, management authority is delegated to various Ship Acquisition Program Managers (SHAPMs), in NAVSEA headquarters. They in turn rely on supervisors of shipbuilding (Supship) field organizations to provide on-site monitoring and direction subsequent to contract award.

Each SHAPM may also be supported by Participating Acquisition Requirements Managers (PARMs) who provide technical management of complex electronic or ordnance shipboard systems during development and procurement.

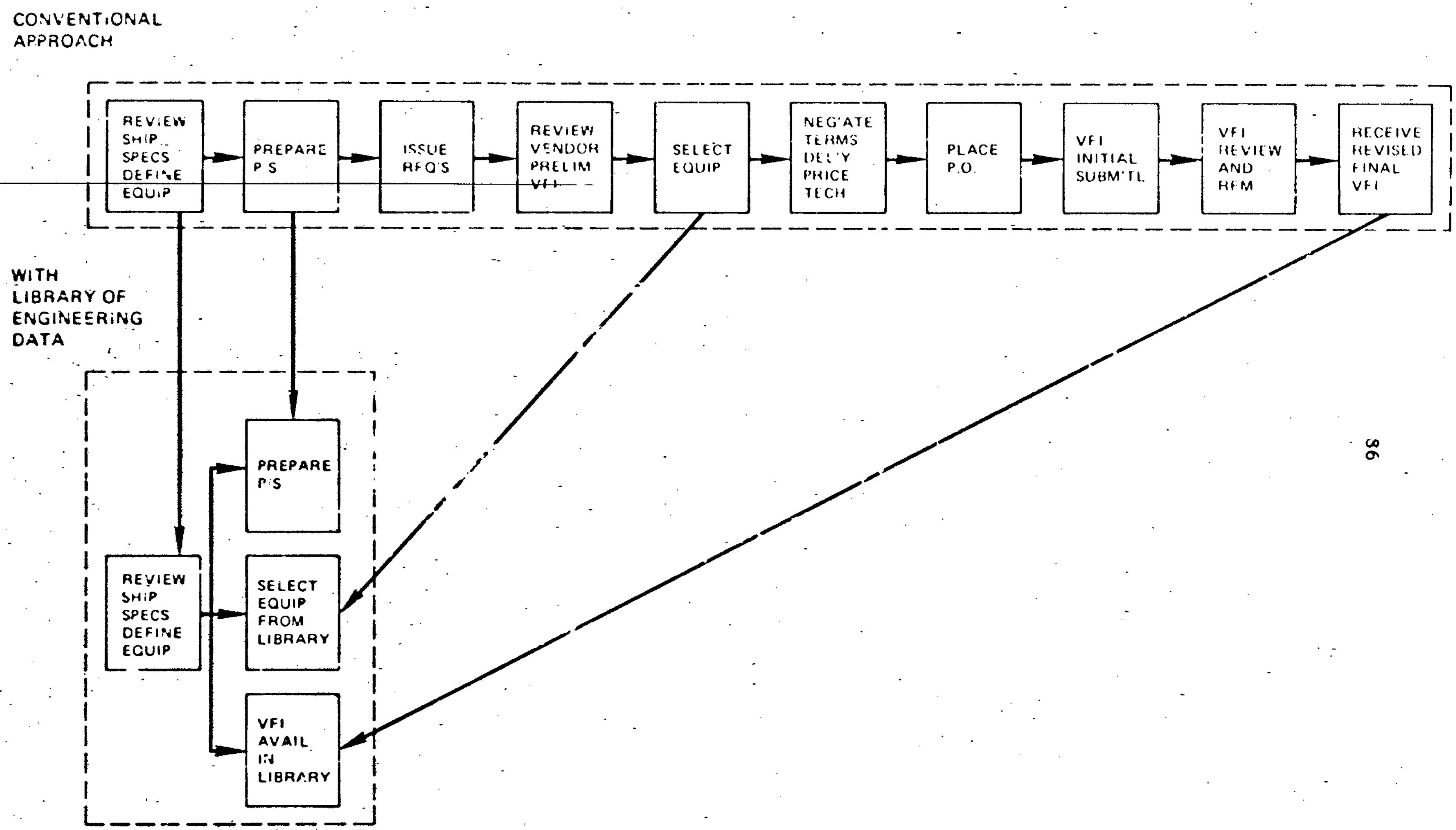


FIGURE 10 Effect of library of engineering data on obtaining vendor furnished information.

SOURCE: Bath Iron Works Corporation.

An example of these intra-Navy relationships is typified by the cable laying and repair ship (T-ARC-7) recently constructed. The SHAPM (PMS 383) was responsible for the total ship acquisition. The shipbuilder was the prime contractor for hull construction and the installation of all shipboard systems. The major mission-related system, the cable-handling and laying systems, was developed for the SHAPM by a PARM, PME-124, in the Naval Electronic Systems Command and provided as GFE to the shipbuilder for installation.

"PARM-responsible" equipments may be provided by the SHAPM as government-furnished material or the shipbuilder may be directed by the SHAPM to procure the equipment from the PARM contractor source.

It is recognized that PARM contractors commence equipment development activities considerably in advance of shipbuilder selection, and that PARMs have a dual responsibility to manage their equipment contractor(s) and to maintain a strong interface with the SHAPM regarding equipment cost, schedules, shipboard support system requirements, and equipment performance capabilities.

Shortly after shipbuilder selection, communication links should be established between the shipbuilder and PARM contractor(s), but with a full understanding of the chain of command for technical and contractual direction, which places top-level responsibility for direction and coordination with the SHAPM.

During the ship construction phase, technical and contractual problems may arise which can directly impact the shipbuilder. Problems which cannot be resolved by the cognizant Supship organization are forwarded to the SHAPM for resolution. If the problems pertain to "PARM-responsible" equipment, the SHAPM will seek resolution with the PARM and the shipbuilder will be advised of the outcome. The SHAPM has to advocate the schedule changes and supporting changes desired by the shipbuilder as engineering and production functions are integrated, and secure PARM adherence and support.

It is important that the Navy speak with a single voice to the shipbuilder, though this does not preclude joint fact-finding meetings between the SHAPM, the shipbuilder, and the PARM. For its part, the shipbuilder needs to use the SHAPM-PARM linkage to obtain zone-oriented data necessary for making GFM compatible with ship sytems and efficient to install.

5

MODERNIZING SHIPBUILDING TECHNOLOGY: PRODUCTION MANAGEMENT SYSTEMS

SCOPE OF MANUFACTURING EFFORT AND OF PRODUCTION MANAGEMENT SYSTEMS

As the Navy's ships become more complex and technologically sophisticated, shipbuilders require ever more advanced production techniques and systems. At the same time, a number of large-scale trends in manufacturing have been coalescing and show promise of transforming the technology of manufacturing, including the ship production process. These trends include (Scientific American, 1982):

- Computers are increasingly being used to perform the paperwork of the manufacturing tasks as well as process control.
- Flexible production systems are starting to replace fixed production systems.[1]
- Automation technologies, including computer-controlled machines, are being introduced and used.
- Individual work areas are being tied together by the computer into a production system.
- The cycle time through the production process is being shortened.
- Consistent high quality is being recognized as a productivity and cost improvement.
- Group technology, the method of classifying parts and assemblies having similar processing requirements, is being used as a means of gaining quantity production experience advantages in instances of limited production. In shipbuilding, this approach is termed zone-oriented construction.

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[1]The difference between a flexible production system and a standardized one has been described by an observer as follows: "Flexible system production is rooted in discovering and solving new problems; high volume, standardized production basically involves routinizing the solutions to old problems. Flexible-system production requires an organization designed for change and adaptability; high volume, standardized production requires an organization geared to stability." (Reich, 1983)

- o Military system complexity is increasing to the point where formalized configuration control systems are necessary to ensure the required quality with the necessary customer flexibility.
- o Just-in-time inventory management is recognized as an effective tool for lowering cost and improving quality.

These trends affect, to some extent, all manufacturing operations. Of particular interest is the way the application of computer and information technology to manufacturing is changing all types of production, including the production systems of shipbuilders and also shipbuilding suppliers.

Figure 11 provides an overview of the steps involved in obtaining and using a sophisticated product. In the context of a naval ship, the top-level node, "get and use product," is the dominant role of the customer, the U.S. Navy. The subject of this section of the report, production management systems, is the manual or computerized systems that support the activity within the darkened node, "manufacture product." These systems may receive and use data from other functional areas, e.g., the "manage product," "design product," and "provide for product logistics" nodes in the figure.

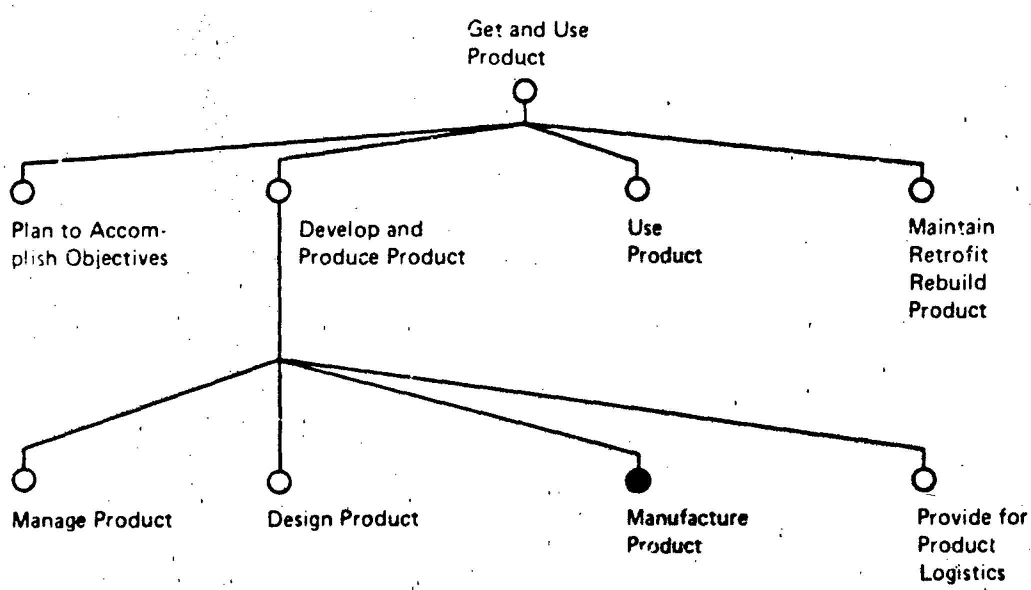

FIGURE 11 Life cycle of a sophisticated product.

SOURCE: Integrated Computer-Aided Manufacturing Program, U.S. Air Force.

The shipbuilder will receive product definition data from the designer or the Navy ("design product" node); overall company plans will be received and followed ("manage product" node); and logistics requirements data, such as spares provisioning requirements, will be received from the Navy and used ("provide for product logistics" node).

Each of the nodes in the figure represents an information generating or using activity and is, in turn, characterized by its own node diagram. The "manage product" node, for example, includes such activities as long-range planning of products and product lines, financial planning, and marketing. Production management system activities receive and provide data to these activities.

A simplified view of a nonshipbuilding manufacturing activity is provided in Figure 12. Production management systems are concerned with the flow of information among the elements of the figure, and with the flow of manufacturing information to other users (or vice versa).

Production management systems are those systems that take product definition data, schedule data, resource availability data, company planning data, and all other data that must be stored, retrieved, used, revised or added to for all activity to be accomplished for producing a product of the required quality, on schedule, and within the required cost parameters. Included are systems for handling data for engineering release (which defines the product) to the delivery of the product with the data required for configuration control, quality control, and maintenance. The core systems include: bill of material, master scheduling, capacity planning, production planning, material requirements, production scheduling and control, and purchasing. The data from engineering might be in the form of drawings, parts lists, and computerized data. The production management systems are used, often with the aid of computers, by every organization in the company to organize, manage, and accomplish the building and delivery of the product to the customer.

In the development of production management systems suitable for shipbuilders it is necessary to keep in mind the differences between manufacturing and construction. In repetitive, or even batch-oriented manufacturing such as aerospace, a prototype is constructed to complete the design, and material requirements are defined based on the prototype experience; significant production runs follow the prototypes; material can be more readily batch-ordered in advance and kept in inventory; and there is opportunity for substituting materials between units under construction to compensate for schedule deviations or component loss, damage, and failure. In construction, such as shipbuilding, nearly every end product is virtually prototype; there are very long (in time) production runs; material definition takes place as detail design progresses; procurement action is phased based on lead time requirements, subject to engineering development, and some may take place relatively late in the program; and there is little opportunity to borrow materials from follow units to keep to schedule or to compensate for lost, damaged, or failing equipment. For a construction (i.e., project-oriented) activity like shipbuilding, it also must be recognized that the engineering function, just like material procurement, must be viewed as supporting the production function; production

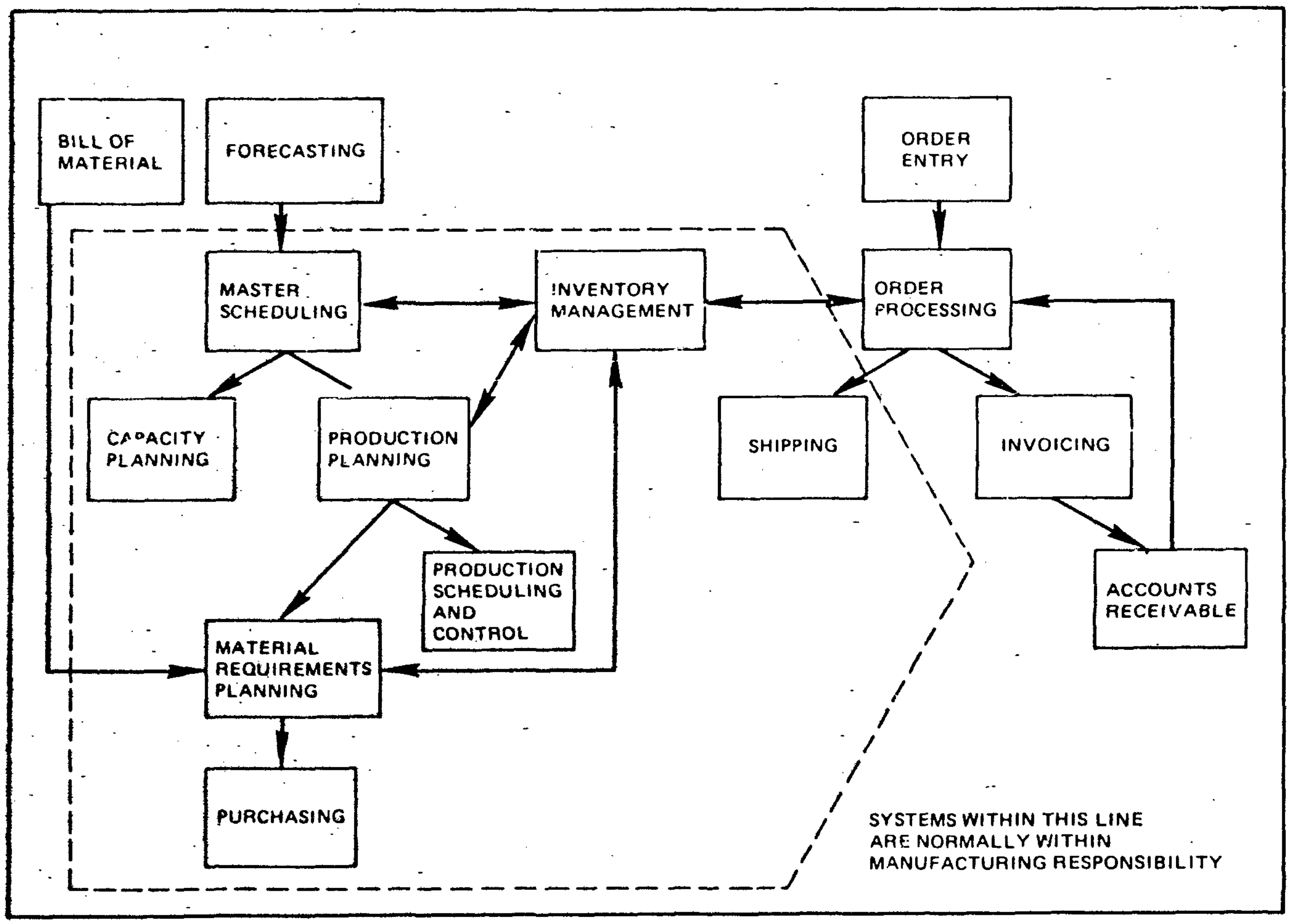

FIGURE 12 Production Management Systems

SOURCE: Booz, Allen & Hamilton

management systems must integrate with engineering management as well as material management. It is further noted that overall system reliability is largely dependent on material selection--especially with regard to components. Engineering, not production, specifies all materials not provided by government. To make Figure 12 fit the shipbuilding case, therefore, material requirements planning would come before production planning. Production is interested only if no other material is available, and not whether the material available is Brand X or Brand Y. Yet another distinctive feature of shipbuilding is the importance of taking producibility into account early in ship design.

Productivity Improvement Associated with Production Management Systems Advancement

Ship production, like all manufacturing, is data intensive. Yet, the various functions (see Figure 11) work with similar data. The data started in preliminary design are merely enriched, modified, improved, and used by the various organizations in doing their jobs. Companies with the most advanced systems have established common data bases for use in all company functions. Over a 7-year period, for example, the Boeing Airplane Company established three data bases for corporate use, including production management systems functions. A business system contains data for production control, parts lists, inventory control. and so forth. A geometric data base handles the master models and the geometry of the products. A design analysis data base holds design analysis data, including product specifications and the results of analysis tests.

Boeing has assessed the effect on productivity of its evolutionary incorporation of computers into corporate activities, including production control. From 1967 to 1979, Boeing was able to reduce its production control work force by 46 percent while at the same time the production management systems became considerably more effective. An example of this productivity improvement is demonstrated by a comparison of the factory parts shortages at the time of roll out of the Boeing 747 airplane in 1968 and the Boeing 767 airplane in 1981. At the time of the roll out of the Boeing 747, there were over 7,000 total factory shortages. In contrast, there were less than 100 shortages at the time of rollout of the Boeing 767 airplane. In yet another example, prior to modernization and computerization of management systems, a manufacturer of coastal craft improved his performance in man-hours, from the first hull to the second by 4 percent. With modernization of management systems, the performance improvement jumped to 53 percent.

Another major U.S. corporation with diverse commercial and defense manufacturing operations surveyed the productivity improvement that could be realized as a result of the modernization or use of production management systems. Using the data gathered during the survey, the corporation estimated that companywide upgrading of production management systems would result in a 17 percent reduction in raw and

in-process inventories, 7 percent improvement in direct labor productivity, 20 percent improvement in indirect labor productivity, and 7 percent improvement in capital equipment utilization. Since completion of the survey in 1979, some 75 manufacturing units of the corporation have conducted structured self-audit programs to ascertain the benefit to be gained from the introduction of improved production management systems. The opportunity identified by these businesses represents a reduction in raw and in-process inventories of between 20 to 25 percent and between $80 million to $90 million improvement in direct and indirect labor productivity. Recent reviews indicate that approximately 60 percent of that opportunity has been realized, with new operations entering into the evaluation process each year.[2]

In addition to direct productivity improvements, there are intangible benefits associated with the modernization of production management systems. More effective manufacturing supervision is achieved by reducing shortages and allowing supervisors to manage people rather than expediting parts. An effective increase in capacity is obtained through more efficient labor utilization. The need for staging is reduced through early identification of shortages. Managers gain the ability to more effectively re-plan and manage the response to changing business conditions. Manufacturing lead times are reduced, as are buffer inventories of long lead-time components and assemblies. Managers gain easy access to key information and the ability to perform "what if" simulations.

State of the Art of Production Management Systems for Project-Oriented Manufacturing

The availability of packaged software for manufacturing control has increased steadily over 5 years. Many software vendors market package systems for control of manufacturing operations. These systems contain all functions necessary to control the manufacturing operation. They satisfy most "standard system" requirements, and are capable of analyzing activity and generating status reports in response to user inquiries. Systems are available that will operate on the complete range of computer hardware, from desk-top microcomputers to very large mainframe computers. Generally, these systems are not integrated with other computer applications such as computer-aided design and computer-aided manufacturing (CAD/CAM), i.e., numerically controlled machines or robotics.

Project-oriented manufacturing, such as shipbuilding, poses a number of different, complex management problems, which limit the

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[2]The committee compiled additional data on the productivity improvement to be realized from modernization of production management systems, which appear in the committee's working paper on the subject.

usefulness of the standard commercial production management systems software. Frequent and extensive changes occur throughout design and production. Projects tend to be of long duration; and are usually produced to order; there is little stability in product configuration. Each project is resource intensive, i.e., labor, material, and capital. Subcontractors are often major participants. Project management involves more reporting requirements, such as status reports, tests, and certifications.

These characteristics of project-oriented manufacturing lead to a number of requirements different from standard manufacturing operations. There are likely to be major bidding, estimating, and budgeting activities. Projects are often segmented using a work breakdown structure. Project management requires calculation of actual (or moving average) cost versus a standard cost estimate. Subcontracted elements often require detailed design prior to ordering. Management systems need to provide for progress billings, labor expenditures, and segregation of costs by ship class, flight of ships, ship designation, contract number, hull number, space and cost class numbers, and work packages. A large number of engineering changes may be necessary during the life of the project. Configuration control will be necessary from design through planning, construction, maintenance, and overhaul.

Only recently have the software companies undertaken the development of production management systems to address the unique control and reporting requirements of project-oriented manufacturers. The U.S. Department of Defense (DOD), especially the Air Force, has played a catalytic role in this, because much project-oriented manufacturing is defense manufacturing. Also, the market for production management systems targeted to project-oriented manufacturing is small, and may not be worth the investment by software vendors alone.

To fill the void of software applications in areas not being addressed by the commercial software developers, the Air Force has initiated the development of manufacturing subsystems, through private industry, as part of its Integrated Computer-Aided Manufacturing (ICAM) program. One of the thrusts of the program is to identify and address critical high-potential manufacturing applications not being provided by the commercial suppliers.

In addition to the ICAM activity, commercial suppliers of packaged software are likely to continue to expand their offerings. With continued development of manufacturing technology towards integrated, flexible production facilities with distributed processors and embedded processing technologies, production management systems will need to be better integrated with CAD/CAM. There are significant areas of data overlap in CAD/CAM and production management systems that provide fertile ground for further integration of the three areas of computer use in manufacturing. The areas of overlap are summarized in Table 13. There are some examples of developments that integrate across these uses of computers. At least one project-oriented manufacturer has developed a system that manages a data base of digital descriptions of geometric parts and controls the generation and delivery of process plans as dictated by the production scheduling system. Another system manages process plans and shop resources and controls the delivery of tools, material, and work pieces to the work stations as dictated by the shop load and schedule.

TABLE 13 Overlapping Data Requirements Between CAD/CAM and Production Management Systems

DATA	CAD/CAM	PRODUCTION MANAGEMENT SYSTEMS
Part Description	Data including part numbers and descriptions. Often excludes purchased parts.	Includes all parts, and additional descriptive data such as unit of issue, commodity code, and planner number.
Bill of Material	Engineering Bill of Materials.	Complete bill of material, broken down by manufacturing phase.
Manufacturing Data	CAM systems contain process plans in much greater detail than in production management systems. Often based on group technology principles to facilitate process planning.	Contains step-by-step routings, standard set-up, and run times. Group technolgy principles could aid scheduling famlies of parts together

STATE OF THE ART OF SHIPBUILDING PRODUCTION MANAGEMENT SYSTEMS

Survey of Shipbuilders

The committee defined the state of the art of production management systems used in naval shipbuilding by means of a survey, the results of which are summarized and assessed in this chapter. At the same time that the work group conducted its survey, its two other investigations of the extent of computerization in the shipbuilding industry were in progress under the sponsorship of the National Shipbuilding Research Program. The Illinois Institute of Technology Research Institute (IITRI) recently completed a survey of computer applications in the U.S. shipbuilding industry (Diesslin, 1984). The second project, managed by the Grumman Corporation, has the objective to identify software tools to enable shipyards and design agents to improve their programming and integration and data exchange capabilities.

The committee undertook its own data collection effort after reviewing the objectives and plans of these projects, primarily for two reasons. First, neither project was formulated to develop necessary information on production management systems, as distinct from other

uses of computers in shipbuilding such as for design and in manufacturing applications. Second, the committee was interested in targeting its efforts on naval shipbuilders, and several of the major naval shipbuilders did not participate in one or more of the other projects. In other words, the data assembled in the other projects are not necessarily representative of naval shipbuilders. Regardless of the limited utility of these other projects to the committee, a wealth of information of interest to shipbuilders is resulting from them.

Participants in the survey included one each of the range of naval shipbuilders: nuclear combatants, non-nuclear combatants, auxiliaries, and patrol vessels. In addition, a leading Japanese shipbuilder participated in the survey. The shipbuilders agreed to participate in the survey on the condition that company identification not be disclosed. Survey participants completed a questionnaire, the substance of which governs the organization of the following presentation. Participants were asked to complete the form twice--once for their shipyard and once for their perception of the average state of the shipbuilding industry. The responses of each of the survey participants were reviewed and concurred in by their senior management.

A summary and assessment of survey results follows.[3] The material is presented in a sequence that covers the range of production management systems, as defined in the preceding section.

Design Definition of the Product

There are very large differences in the amount of design computerization in the industry. A number of companies have introduced computer graphics systems (Diesslin, 1984). They are doing much of their calculation work on computers and detail drafting is being done with computer graphic systems. The basic designs still appear to be largely manually prepared. The average shipbuilder has very little computerization of the design process.

Those companies that have computerized the design process have found that they have enhanced their engineering capability, reduced response time, reduced engineering errors, improved the capability to standardize ship components and units, provided more customer flexibility, and reduced the engineering hours to do the same tasks. Manufacturing has found the data to be more accurate and timely. In addition, different functional groups in the shipyard have access to the same information. The use of computerized data from engineering has provided improved data consistency to other users.

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[3]A tabulation of survey results appears in the report of the Work Group on Production Management Systems. Limited copies are available from the Marine Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418.

Those surveyed found that further computerization will allow production to better plan work, will provide for increased integration of the design process with production, and as a result will improve productivity and reduce flow time. Data redundancy can be reduced through computerization and integration, particularly if common data bases are set up and used. Some are convinced that follow shipyards can reduce their front-end costs significantly if the design of the product has been computerized and the design can be transferred in digital form. However, a number of issues have to be resolved before this can come about: legal responsibilities for accuracy of digital design data; mechanisms for transferring product model relationships and information in addition to drawing formats; and incentives to encourage all parties to participate.

The contraints on computerization were found to be the lack of skills in the industry and priority in the company. The most serious problem is that of finding or training people to meet the skills needed for the development, implementation, and operation of the new systems. There is a shortage of computer literacy and fluency in this country. This problem is not at all limited to this industry. The initial costs of computerization are high, making wholesale conversion difficult to justify on a year-by-year basis.

Use of Product-Oriented Work Breakdown Structure. Product-oriented work breakdown structure is a form of group technology used in much of industry as a means of improving productivity, even for a variety of requirements, by grouping nonidentical parts, assemblies, and tasks by their common characteristics (Okayama and Chirillo, 1980).

Product-oriented work breakdown structure concepts are used extensively in a manual mode by naval shipbuilders. The extent of computerization by the shipbuilders surveyed varies from no computerization in one shipyard, to extensive computerization in two shipyards. The respondents found that computerization provides a good foundation for more efficient process planning.

Those surveyed believe that the average shipbuilder makes limited use of product-oriented work breakdown structure and makes very limited use of computers in this activity.

Those using computerized product-oriented work breakdown methods were able to achieve more standardization, and improved control over detail planning and the communication of plans, and have found materials and parts more readily available. Using product-oriented work breakdown structure, shipbuilders can effectively integrate schedules and monitor and control diverse activities by process and work packages.

The constraints on computerization of product-oriented work breakdown methods have been found to be the need for specially trained people and the systems incompatibility resulting from vertically integrated systems rather than horizontally integrated systems.

Engineering Callout of Materials, Details, and Assemblies. Materials callout in engineering and procurement operations appears to be one of the most computerized functions in the industry. This is typical of other industries. Those surveyed found that computerization provided more disciplined engineering release, timely procurement, improved material availability, reduced flow time, minimized error, improved change handling, and improved parts and component standardization.

Configuration Control. Naval shipbuilders use a mix of manual and computerized configuration control systems. Generally, more advanced companies use computer systems for tracking and status reporting while the average shipbuilder performs all of these functions manually.

Those with significant computerization found that they have better access to data, can process changes more rapidly, and have improved configuration control with reduced costs and improved management visibility.

Those embarked on computerizing their systems also believe that they will be able to provide more timely configuration data to all concerned organizations, reduce response time to answering questions on changes, improve cost estimating, improve documentation for fleet maintenance and overhaul, and improve decision making and the process of incorporating engineering changes.

Survey respondents noted the aforementioned skill shortage and development cost problems. One investigator found that change management has been a problem because of the nature of the computerized system. Other companies have found that they needed computerized systems to manage changes properly.

Schedule Development, Control, and Monitoring

Naval shipbuilders use computers extensively in scheduling, controlling, and monitoring, where the average shipbuilders are partially computerized. The degree of computerization used at the various levels of scheduling activity by Japanese shipyards is dependent on the level of detail and the responsiveness required. Figure 13 graphically illustrates this application in one Japanese shipyard.

The top and the bottom levels of schedules in the figure are generated manually. The top level contains only a small amount of data and sees only infrequent revisions. The lowest level of schedules is prepared manually every week by the assistant foreman with the assistance of his work crew (10-15 workers). By having the workers participate in the development of the schedule for their work assignments during the coming week, the Japanese foreman obtains a much better commitment to the schedule thereby providing full support of the overall program objectives.

It also must be noted that European shipbuilders have developed and implemented computerized production management systems and successfully used such systems over a period of 10-15 years. Several shipyards, including Kockums in Sweden, have developed fully integrated systems covering items such as drawing development, lofting, planning and scheduling, materials cost reporting, and engineering calculations.

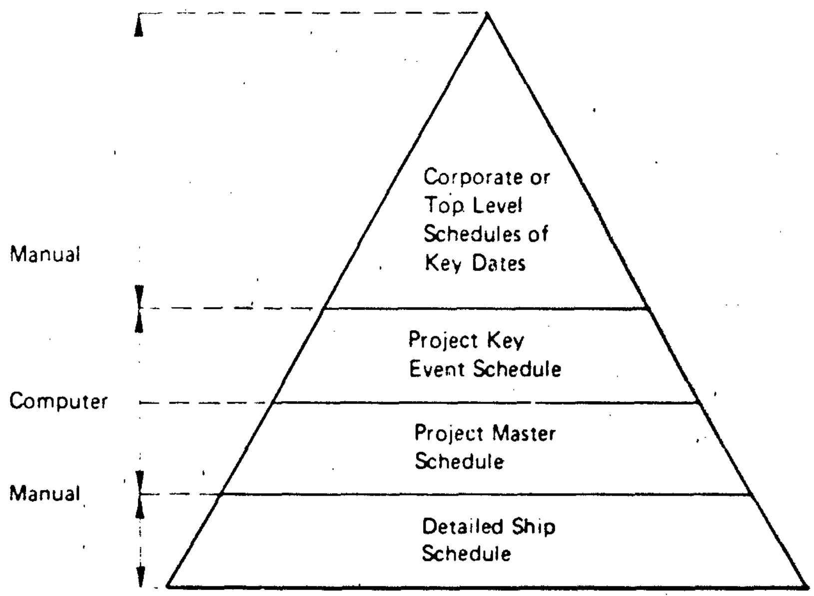

FIGURE 13 Computerization of shipbuilding schedules in a Japanese shipyard.

The computerized systems provided rapid access to data, high management visibility, and better retained learning for schedule development and data retention; made scheduled changes easier; and reduced manpower shortages. They also provided more accurate schedules, a more comprehensive schedule development process, and a better opportunity for workload leveling of manpower and facilities. One company found that they were able to do a much larger job (two major programs instead of one with 46 percent fewer people) and reduce shortages to a small fraction of what they were previously.

The ability to respond rapidly to revised business plans is a major advantage. Reasons for revised plans include new or altered customer damand, internal modifications to improve the system, and disaster recovery. An example of this capability is the modification of fabrication schedules. The process ranges from the development of new detail schedules to the resultant action on the shop floor and at the vendor. It is not difficult to imagine the magnitude of misdirected resources with nonmechanized, manual systems which take far longer to update. The process of revising schedules for an entire product line can be accomplished within a week; manual systems require up to three months. In addition to the flow time saved, the manpower required to manually change fabrication schedules is greatly reduced.

Constraints on computerization were found. Coordination was found to be cumbersome with multiple nonintegrated systems. Credibility was diminished because capacity and loading were not integrated into the schedule systems. The Japanese noted that there are often discrepancies between the schedule data base and actual schedules. They also believe that the computer systems cannot incorporate all the factors influencing the production schedule, thus output is not reliable. It should be noted that these concerns run counter to aerospace industry experience as well as the experience of some shipbuilders in the very early stages of integrated computerization.

Production Planning

Some shipbuilders surveyed use manual production planning systems, while other companies' systems are partially computerized. Respondents consider that the average shipbuilder makes very little use of computers in production planning.

Material systems are computerized in some of the companies that participated in the survey; this activity is at least partially computerized in the average shipbuilding company.

Naval shipbuilders use computers in their outfit and structure planning, whereas the average shipbuilder is believed to perform these functions manually.

Assembly and erection planning was found to be a mix of manual and computerized systems.

Capacity requirements planning was found to be primarily manually performed. Some computerization is present but integration with other systems was not evident.

The survey disclosed that those that have computerized production planning functions have achieved more cost-effective planning, improved management effectiveness, made drastic reductions in shortages, obtained more realistic and accurate scheduling of shop work, and improved material requirement planning and tracking.

Constraints on existing computerized systems noted include inadequate use of near-term production schedules and shop load data to control shop floor activities.

Procurement

The material procurement system was found to be the most computerized production management system with even the average shipbuilder being partially computerized.

Many benefits have accrued to those that have computerized, such as high management visibility, improved material procurement and accountability, better data availability, reduced manpower per unit of material, improved tracking of vendor orders and deliveries, more timely issuance of purchase orders, and ability to minimize stock quantity.

One company noted that it had set up a system to provide visibility relative to the availability of government-furnished equipment. This system is no longer used because of difficulty encountered in keeping the information in the system current.

No disadvantages were noted other than finding the skills and funds to develop, implement, and maintain the systems.

Material Storage and Handling

Naval shipbuilders' material storage and handling systems generally are not computerized. Status and location records are computerized in the average shipyard.

The survey participants found that computerization reduced clerical effort and improved material availability.

Those companies that were improving their capability were convinced that they would have more rapid access to availability data, less expediting, more rapid access to material and parts, higher levels of material accountability, better management visibility, and easier and more timely delivery of material to the work site.

No constraints were cited other than the lack of skills needed for system development, implementation, operation, and the associated costs. Nevertheless, experience in other industries suggests that data accuracy problems are a major constraint upon the effective use of computer-based inventory management systems. Accuracy must significantly exceed 95 percent for users to trust and use formal systems. Without this high level of accuracy, informal systems and procedures develop. When this happens, investments in computer systems are often lost.

Production Management and Control

Computerization of the shop floor, and erection and outfitting operations, is limited. There is little evidence of integrated systems. Some companies have computerized shortage control systems.

Companies using computerized systems found significant advantages including improved performance to schedule, fewer shortages, discrete schedules and routings prepared for all components and assemblies, improved quality and consistency of production instructions, improved visibility and responsiveness, reduced manpower requirements, reduced inventory of work in process, reduced production flow time, level-loading, and increased effective production capacity of current facilities and manpower.

In some companies, difficulties in reporting production progress accurately and quickly were cited as constraints on using computerized systems. Two features of the data reporting problem are noted: (1) work packages must be defined in sufficient detail for progress to be measured and recorded, and (2) work reporting systems designed for cost collection systems may not support assembly and shop floor control requirements. Other constraints mentioned included skills shortage and low priorities for spending placed on this sort of project.

Cost Collection Systems

The cost collection systems were found to be in transition from a cost-by-system basis toward a cost-by-zone, area-and-stage basis. As production methods are modernized to take advantage of zone orientation, it is apparent that the cost collection system will have to be modernized. Very little cost data are collected to the process level. Some cost data are collected to the work package level. Most cost data are collected by trade class to a unit assembly level. Because of the way costs are collected, the cost drivers, which are process-related, tend not to be visible. The Japanese company was found to report man-hours at the department, shop, and work station level by job, hull, engine, and electric. Capital requirements are reported by cost center and then by job, hull, engine, electric, and cost code.

Quality Assurance

There is little computerization in the quality assurance area other than the tracking of discrepancies, test status, and the quality assurance requirements and inspection approvals that are specified by computer-released planning. There is also very little computerization of configuration control. In most cases, the quality assurance organization had the responsibility of verification to drawing prior to ship trials and delivery.

Some companies are looking at these activities for further computerization to better account for changes; provide more reliable maintenance and repair data; reduce rework when process planning is more closely integrated with inspection, and quality assurance, and process quality assurance; and improve adherence to drawings and specifications with reduced manpower.

Production Simulation

Production simulation as a tool to aid production decision making has been used by other industries but there is no evidence of its use by shipbuilders. At this stage of systems development, there appear to be no sources of reliable data to support simulation effort. There is a lack of user knowledge relative to simulation. This activity cannot be pursued until the basic systems development discussed in this section has been accomplished.

Assessment

The survey produced contradictory information concerning the relative integration of production management systems in the naval shipbuilding industry. Detailed review of the responses reveals that only one production function, material procurement, has a significant amount of horizontal integration. One company making extensive use of

horizontally integrated aerospace batch systems indicated that it had made productivity improvements.

It appears that shipbuilders are feeling some of the pains of computerization that the aerospace industry suffered about 10 years ago. All companies surveyed have concluded that there are significant advantages to be gained from computerization. They have taken action over the last 2 or 3 years that is in the right direction. However, the shipbuilding industry has the advantage of learning lessons from other industries, such as aerospace, in which production management systems are more completely integrated and computerized.

Some shipbuilders are starting to use structured analysis and other aerospace systems development tools. When properly applied, the tools materially aid systems development.

Systems development justification does not follow a specific pattern. In some cases, conventional return on investment guidelines are followed. In other cases, developments are considered necessary on the basis of company position in the industry, the need for better capability, or contract requirements.

An attempt was made to discern the systems planning horizon of naval shipbuilders. Some companies have 1-year system development plans. One company has found that it must fine tune its 1-year plans, plan budgets 2 years ahead and establish their basic plans for overall system development and integration for 5- and 10-year periods. Aerospace industry experience has shown that plans are most useful if they span at least a 5-year period. There is very little in the development of computerized systems that does not take 2 or more years from planning to completion.

Cost of Modernizing Production Management Systems

While the committee's survey did not gather data on the cost of modernizing shipbuilding production management systems, one shipbuilder who is modernizing and computerizing production management systems provided the committee with some information on the level of effort directed to this end. This shipbuilder has been involved in a substantial program of new ship construction since 1976 and has invested $120 million in capital improvements over the life of the program. This has included $3.5 million for computer hardware and peripherals to upgrade production management systems.

Hardware costs represent only a relatively small part of total system improvement costs. Other costs have included the time and effort of management personnel, software costs, developing and maintaining suitable office spaces, and purchase of related supplies and services. This shipbuilder estimated the total cost, including management effort, of installing and implementing or upgrading management systems at about $12 million from 1976 through 1983. For each of the past 2 years, this activity has been budgeted at about $1.1 million and 30 man-years.

A different approach to the same question is to apply rules of thumb of the general manufacturing environment. A typical investment

to design, program, and implement a program management and materials management systems capability is $1.5 million to $3 million, not including the cost of hardware or software. The cost of operating these systems runs about 1.5 percent to 3 percent of the revenue. So, a $500 million industrial company would incur expenditures of up to $15 million annually to maintain and operate the system.

State of the Art as Defined by Navy Contract Requirements

When a naval vessel is designed, an engineering data base is created and then maintained over the life of the vessel. The engineering data base supports vessel design, construction, supply, operation, repair, maintenance, and overhaul. In each of these steps, the data base is accessed, added to, or otherwise altered by users who are unknown when the data base is established. While the data base originates with the Navy, the shipbuilder (or detail designer) plays a key role in completing the data base because of the volume of data added to it in detail design.

Traditionally, a ship's engineering data base has been in the form of engineering drawings and other technical documentation. However, computer models offer much richer communications media than engineering drawings, and the Navy is moving in this direction (see discussion of the Information Systems Improvement Project (ISIP) in Appendix C). Within the Naval Sea Systems Command (NAVSEA), one program group is establishing a computerized, stand-alone description of a ship design. In addition to geometry, the system will contain data on components, material, shape, orientation, nomenclature, and performance.

A more visible manifestation in the Navy is in certain requirements included in new ship contracts. Both the contract for the LHD 1 and the proposed contract for the DDG-51 specify that the lead ship design and construction contractor provide a magnetic tape copy of the Ship Select Record drawings (formatted in accordance with Initial Graphics Exchange Specifications (IGES)). These drawings, about 5 percent of those used in ship construction, are the appropriate drawings to be initially designated for magnetic tape copy inasmuch as they represent the final shipboard installation of important features, systems, and arrangements, and are required to be updated throughout the life of the ship.

It is prudent for the Navy to start computerizing the engineering data base on a specific, limited scale to resolve the uncertainties and unforeseen problems and thoroughly test the interchange of the data. It would be a mistake to overspecify this data exchange requirement in near-term shipbuilding contracts, thereby saddling the respective contractors with high-risk deliverable data requirements on a broad scale.

However, this approach begs two important concerns. First, the next major Navy shipbuilding program in which the data base requirements could be invoked more comprehensively is years away. Second, a myriad of data needed for the construction, operational maintenance, repair, overhaul, and conversion of the ship and its installed equipments and systems is not covered by the requirement. For example,

there are ship equipment (vendor) drawings, technical manuals, and test reports, to name a few categories, that if properly maintained and updated, provide information that is either vital or useful for ship maintenance and industrial support planning purposes throughout the ship's life.

A Supplier's Perspective

A supplier of hull, mechanical, and equipment items addressed the committee on computerization of engineering data bases and management systems as follows: "It is our view that engineering change notices, design reviews, drawing approvals and similar matters will ultimately take place over terminals and data lines. Thus, we are committed to CAD and are doing the necessary internal planning and external contacting to move with our customers. Meanwhile, our internal operations are more and more based on computer orientation. This includes, but is not limited to, stress analysis and modeling, design graphics for interference fits, automatic inspection tools, CNC tools, and cost and historical accounting systems.

"There are a number of examples we could give which illustrate the positive impact of computer-generated data bases, aside from the obvious savings in time. Shop loading projections and parts status records enable manufacturing management to react quickly and implement contingency plans to reduce cost overruns due to unexpected events on the production floor. This facility enables us to react more promptly and accurately to requests for cost and schedule changes when the shipyard wants to explore what-if scenarios with proposed changes. As a recent example, for the CVN-71 deck edge elevator, we were able to change a planned 24-month manufacturing period to an actual manufacturing period of 18 months and deliver the unit 6 months ahead of the original schedule. This was done without severe impact on other work in progress or inefficient overtime and dead spaces because of our ability to track actual vs. planned progress and use alternate approaches developed through the manufacturing data base on a real time basis. It is also a time saver to have the computer prepare our work process sheets, cut sheets, and other documents or instruction for the shop floor.

"Another great time savings comes through the use of spread sheet programs by our financial and estimating people who can quickly give us projected effects of jobs we are bidding on overhead and general and administrative (G & A) rates if we win the job and also if we don't. With proper management attention, these analyses permit us to be very competitive in our pricing strategy and also help greatly in controlling costs. All of this, at the end of the day, leads to reduced costs to our customer, the shipyard which--we hope--are passed on to the Navy.

"Of great value to our actual work force is the historical data and schedule record when kick-off and weekly progress meetings are held. From these records, the work force is reminded of what was done and it helps plan what is to be done now."

IMPROVING PRODUCTION MANAGEMENT SYSTEMS

Planning for Systems Modernization

A recent study indicated that developing and applying production management systems is complex and very few firms regard themselves as particularly successful in this area.[4] In fact, only about one out of five firms making significant investments in developing modern production planning and control systems believe that they have achieved the kind of return on their investment in systems they targeted at the outset. While there are a number of reasons why companies fall far short of their expectations, one clear reason for such failures is inadequate planning before launching a systems development effort. This section explains why it is important to have a plan for management systems modernization.

The Importance of a System Development Plan

The complexity of the production management systems challenge for the defense manufacturer is inherent in the complex supply chain through which plans, parts, and subassemblies move to become finished products. Figure 14 indicates the many organizational functions and physical steps through which information and as materials move from planning to execution. This supply chain begins with the pre-production functions of engineering, production engineering, and tooling. In these stages, initial designs are refined and issues of producibility are introduced. The supply chain then moves through the various operating functions: material, fabrication, and assembly. While the supply chain appears to have a number of discrete organizational barriers, some functions such as quality assurance and finance necessarily span all of these organizational units.

Because a supply chain can be represented in terms of organizations, it is typical to find responsibilities divided along organizational and functional lines. Over the years, the planning and control systems that have been developed have followed organizational segmentations. As a result, systems tend to reflect the needs, biases and operating practices of individual organizational units. For example, material will have such functions as purchasing, purchase order creation and tracking, supplier control, and in some cases physical material control systems unique to its requirements.

Systems developed along organizational lines use some degree of system integration. That is, a number of different data sources are integrated to avoid duplication of collection or subsequent processing. However, this integration has tended to be vertical, that is, from

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[4] Jack Moore, Booz, Allen and Hamilton, Inc., personal communication, February 27, 1984.

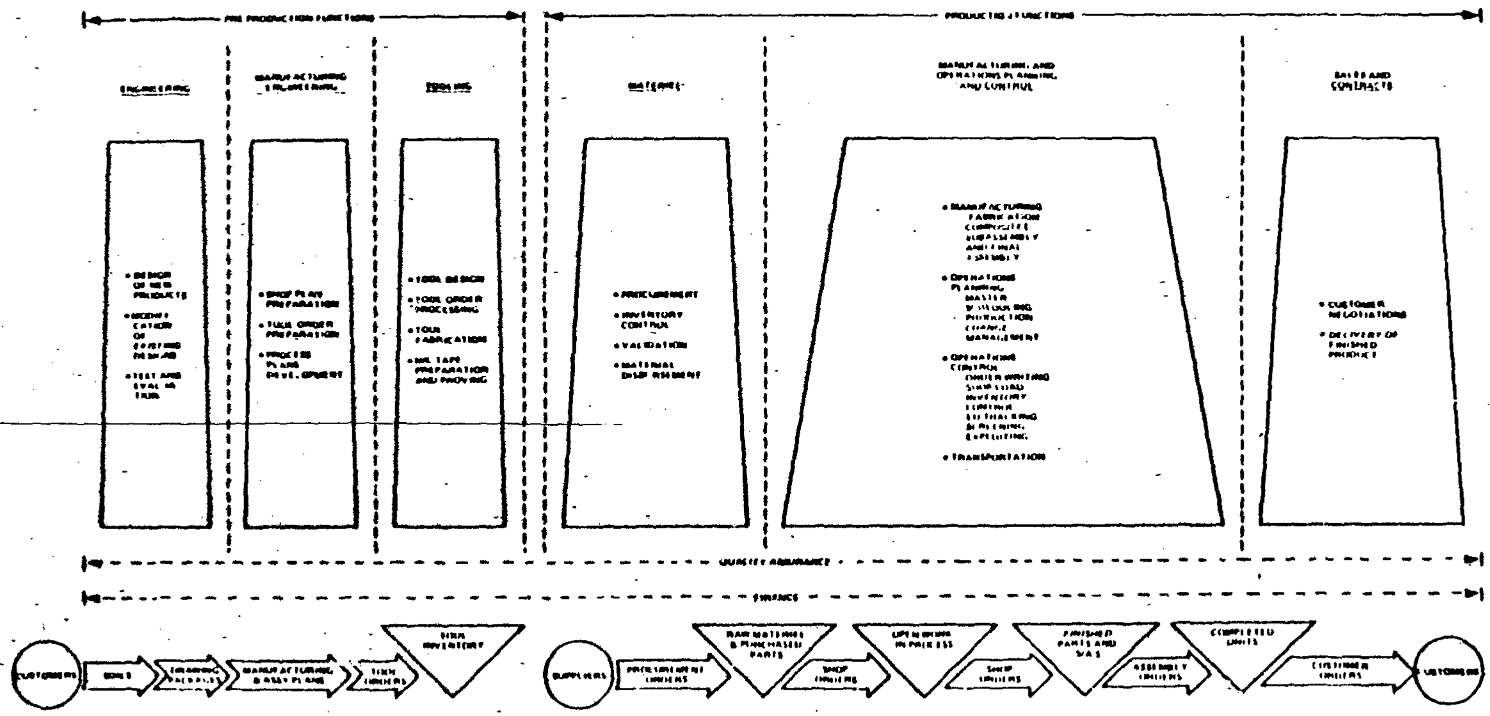

FIGURE 14 Typical Government Contractor Parts Supply Chain

SOURCE: Booz-Allen & Hamilton, Inc.

top-to-bottom within a particular organizational unit. This is not necessarily bad, since data are collected at the bottom of the organizational hierarchy and selectively refined until senior management has the essential pieces of information it needs to plan and control the business.

While production management systems used by most defense contractors including shipbuilders demonstrate some degree of vertical integration, there is relatively little horizontal integration across the supply chain. Shipbuilders' production management systems, by and large, do not talk across organizational barriers. Instead, the emphasis has been on interface, usually of a manual nature. The absence of horizontal integration frequently results in extensive delay and distortion of information at all the many functional interfaces throughout the supply chain. The result of this delay and distortion is to make management's job across the supply chain difficult, if not impossible. Information recognized by one functional area is frequently not recognized by another. Different functions speak in different terms with different objectives. In an age when the DOD customer and foreign competition are forcing the defense contractor to achieve greater productivity, this absence of horizontal integration across the supply chain is clearly not acceptable.

In short, effective control of a manufacturing operation can only be accomplished when the core systems (see Figure 14) are fully integrated, not just vertically integrated within functions, but across the entire supply chain. Horizontal integration can be facilitated by proper definition of the roles of participants in a Navy program; in particular, those of the lead and follow shipyard. Establishment of mechanisms for transferring the design and design relationships in digital form is a necessary step towards integration.

While it would seem fairly obvious that integration across the supply chain is necessary, very few companies have actually been successful in planning for and achieving this kind of integration. A principal reason for this is that there is seldom a long-term plan for production management systems modernization that places integration on a par with many of the other functional objectives to be attained. This is not to say that defense contractors do not provide plans to guide system design activities. Rather, their plans are inadequate because they are generated by a bottom-up approach, as opposed to top-down, long-term commitment.

Although that might seem appealing, what often results is simply a "wish list" of functional capabilities in various kinds of report formats that individuals would like to see. Such wish lists seldom recognize needs for key interfaces or integration points and usually maintain a functional as opposed to integrated focus. Plans typically reflect a very parochial attitude of functional management that is out to meet its own needs, often unaware of the impact on other functions. As a result, functionally oriented, piecemeal systems approaches are frequently adopted in stand alone, "local" systems. Management of the overall supply chain almost always suffers as a result.

A well-defined systems specification and development plan to guide systems modernization can also avoid situations in which formal

planning and control tools are subverted by rules of thumb, such as calling parts to be kitted 6 weeks in advance of need date so that shortages can be identified.

Development of a plan for systems modernization is an essential first step in moving to a more productive manufacturing environment. A plan, if properly framed, will not simply automate existing systems, it also will suggest changes in production processes and organizational structure that provide for greater productivity as a result of improved system tools.

The planning process includes identifying and specifying system requirements, assessing the effectiveness of current systems, identifying and evaluating alternative developments and approaches, and preparing the long-range plan.

Planning and Change Control

Implementing a plan for systems modernization necessarily involves change, which threatens the status quo and produces discomfort. Most organizations do not adapt to change easily. This is particularly true for complex bureaucracies such as government agencies, financial institutions, and manufacturing companies. Successfully managing change is one of top management's most important and challenging responsibilities. Flexibility is an important part of the planning and change processes pursued by management so that the inevitable changes that occur over time, as a result of vertical and horizontal communication, can be accommodated.

One of the principles of good systems planning is user involvement. As opposed to system installation--essentially a responsibility of the management information system--implementation must be planned, conducted, and monitored by senior functional managers whose departments' success will be influenced by how well the new systems perform. Furthermore, the system implementation needs to be directed by corporate/company officer-level functional managers, as well as managers of the individual modules affected by the new systems.

Plan implementation will have to accommodate evolution not revolution in an active ongoing business with the objective of minimum disruption of work in progress. Equal emphasis needs to be placed on the transition phases from the old to the new systems as is placed on new system design.

Relative Importance of Modernizing Shipbuilding Practices vs. Management Systems

Good systems cannot be designed and developed unless a company knows how it is going to run its business in the future. This means that there must be a significant effort directed at the methodology of building ships and at the same time how the data is going to be handled. The computerization of the design and production process can have a very significant impact on organizational structure.

There are differing opinions among the experts. Some say that when looking to the future you must look at both shipbuilding methodology and systems. Others indicate that it is necessary to get the shipbuilding methodology revised and then attend to production management systems modernization. Noted below is a statement in support of the latter view, made by an executive of a shipyard that constructs noncombatant naval vessels.

> As a practical matter, the most significant productivity-related problems are not solvable through the application of computerized management systems. Most of these signficant problems currently can be characterized as institutional, methods (process) or people-related. Institutional problems include those having to do with the Navy-shipbuilder relationship as regards design changes, the absence of a body of standards and the shipbuilder-vendor problems of design information and material lead times. The method problems span the gamut of the shipbuilding process from drawing development to unit accuracy control. These are problems or implementation within an organization as opposed to technical problems. The people-related problems include those from the lack of sufficient numbers of formally trained shipbuilding engineers, to the ability of people to positively adjust to a fast pace of change.
>
> Improved production management systems will aid shipbuilders to improve productivity only after the current changes in methods, and the resulting organizational changes have been in place for a sufficient period to allow for accurate description of the new production system's information requirements.

Those experienced in production management system development, application, and utilization agree very much with the first paragraph. They are firmly convinced, however, that the systems analysis must not wait until after the changes in the methods and organizations have been put in place because the hardware and software of production are truly interactive.

Document-Industrial Engineering

There is a governing industrial philosophy that all production activities, including the release of engineering drawings, need to be scheduled and controlled. This scheduling philosophy has been applied to the construction of some Navy ships and has been found to be very beneficial to production. The scheduling philosophy known as Document-Industrial Engineering (DIE) is presented here so that naval shipbuilders can take advantage of it in their systems planning activities.

The DIE process provides a method in which the numerous activities of a construction program are identified and placed into a time

relationship, and events prioritized. Data resulting from this process is sufficiently detailed to provide early problem identification to assist program management in its ability to manage.

The process is a method of communicating engineering release data, after preliminary design and prior to detail design, to the production organization so that a production schedule may be developed in advance of drawing release. The logical insertion of a DIE phase in a Navy shipbuilding program would be between the preliminary design and systems engineering phase (i.e., functional design) and the detail design phase. Following completion of the DIE phase, detail design will proceed according to committed schedules.

The resultant schedule will contain milestones for procurement, tooling, planning, fabrication, assembly, installation, and test and trials. After all milestones are negotiated between the affected organizations, compliance to these commitments is tracked throughout the engineering, tooling, and planning phases of a program.

Following the completion of preliminary design, the engineering division, working in coordination with the production division, divides the ship into major assemblies and installations (i.e., hull block plan). From this division, a Production Identification Number (PIN) is assigned, normally related to Work Breakdown Structure (WBS). Each PIN contains identification of parts, assemblies, materials, and other items that make up this package. The PIN work statements are used by manufacturing engineering to prepare Commitment Development Schedules (CDS). CDS contain assembly sequence, part requirements, equipment, tools, and material requirements.

CDS are then used by the industrial engineer to apply start and completion dates for each element of the CDS. Standard flow times are applied to each element. Two outputs result from this activity: (1) a number-one flow unit schedule for the first ship fabrication and assembly and (2) engineering drawing release date requirements. Working schedules are derived from the number-one unit flow schedule. Industrial engineering uses the engineering release date requirements established by the CDS flow times to negotiate the final drawing release dates with engineering. The results of the DIE negotiation are documented in a DIE document. The design phase is tracked against committed dates and noncompliance is reported for management action, as necessary.

Successful implementation of DIE depends upon the breakdown of ship design into manageable packages. These packages are then individually monitored for all those functions that affect their production progress to assure that items necessary to support the production process are available on schedule to support the next scheduled event. Slips in the schedule are readily identified so that management attention may be applied and timely corrective action taken. The potential for loss of program control is avoided, in theory, if each behind schedule item is properly managed.

Success of this concept depends on applying the proper resources early in the program. Resources include engineering to initiate the DIE process and design-manageable work packages in coordination with production. Also included in these resources are manufacturing engineer planners who contribute significantly to the DIE process.

Planners establish the assembly sequence and identify the supporting elements. Industrial engineers contribute to the DIE by establishing schedule dates, flow times, and preparation of the number-one unit flow schedule. An important part of the industrial engineer's DIE activity is the negotiation of engineering release dates, which provide the basis for the entire program schedule.

Applying the DIE concept to Navy shipbuilding requires changes in the ship design sequence. Detailed design would need to be expanded into more definitive packages than now is the practice. More extensive tiering of parts, subassemblies, assemblies, major assemblies, and installations would be necessary. Currently, this type of tiering is not practiced by most U.S. shipbuilders. Larger staffs of manufacturing and industrial engineering personnel would be required to perform the DIE process and to plan, schedule, budget, track commitments, and assist in managing each program. This concept would probably be a new approach to most U.S. shipbuilders.

Paybacks may be expected from the use of the DIE concept on a program. Listed below is a summary of anticipated benefits.

- A priority of engineering releases is established. Production will receive engineering data in the sequence required to support schedules.
- Management visibility is made available at an early phase of a program. All organizations will work to a common plan.
- Reduced program costs may be expected by improved work package definition and delay avoidance.
- Early identification of work packages enables engineering to more accurately estimate manpower requirements and phasing of their manpower.

Shipbuilding Management System

There are significant benefits to be derived from an enhanced, modern, up-to-date, shipyard management system which could be used by all Navy contractors. The cost of such an effort as visualized is greater than any one yard could afford. The total cost however, in the view of the committee, would be far out-weighed by the benefits. If such costs could be shared, the Navy could act as a catalyst in the development of such a program while still not mandating its provisions for characteristics. Such support could be justified on the basis of the significant potential savings to the Navy as well as the ultimate achievement of a life-cycle data base for all aspects of ship design, construction, operation, overhaul, and repair.

6

SUPPLIERS AND NAVY SHIPBUILDING

This chapter presents a perspective of the supplier-shipbuilder-Navy system. The committee addressed this subject with a conviction that the system is more readily changed at the initiative of the Navy than of suppliers. Furthermore, the Navy, as customer, will benefit most directly from improvements.

While the committee was interested in the very great effect of suppliers' productivity and lead times on naval shipbuilding, an examination of the productivity problems of electrial, machinery, and equipment suppliers was beyond the scope of the project. This chapter focuses on the interrelations and productivity of suppliers, shipbuilders, and the Navy as a system.

As has been noted, hull, machinery and equipment (H,M&E), and combat and electronics systems suppliers, contribute two-thirds of the value added in new ship construction.[1] It is, furthermore, no secret that many naval suppliers have experienced difficult times in the last decade. Excessive capacity has elevated facilities rationalization to a position of paramount importance. A key element in decisions concerning facilities rationalization is the size and viability of the markets the facilities serve.

For many suppliers, especially H,M&E, naval equipment represents a small highly specialized market segment. The manufacture of naval equipment often disrupts normal production and demands additional special facilities or procedures. These interruptions or special services can increase the cost of standard industrial products.

Furthermore, the structure, conditions, and terms of naval acquisitions control, to a considerable extent, the interface of suppliers with shipbuilders.

The government's requirement that suppliers' cost collection and accounting systems conform to government standards affects internal management procedures, especially financial accounting systems. Also, a number of tests and quality procedures are required of naval

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[1] This estimate is representative of a major combatant. The contribution is somewhat less in auxiliary construction.

manufacture, which are not normally required in other types of business. These include full material traceability, radiography and other nondestructive testing, and shock and vibration resistance, to cite a few. Careful planning and implementation is needed to assure compliance with rules, procedures, and specifications. These financial and technical constraints demand a disproportionate share of management's time and attention.

The constant corporate pressure to trim operating costs and the small size and special nature of the naval market make it difficult to justify special facilities to meet Navy requirements. Thus, over time, some suppliers have discontinued or are considering discontinuing the production of naval equipment leaving the Navy with a few, one, or no domestic sources of supply (see case study of quiet bearing industry in Appendix B for an elaboration of these trends).

Since the naval market is influenced by the political process and the perceived and real needs for national defense, little can be done outside the political process to increase its size. Barring a major conflict, it will remain relatively small. However, there are a number of issues, which if properly addressed, will make the Navy marketplace more attractive to equipment and material suppliers. A special concern, in the case of suppliers, is that the relatively small market for marine products has resulted in a significant reduction in the number of potential suppliers. In some instances, domestic sources of marine products have been eliminated or reduced to a single company. This is a serious issue, since the supplier base is an important element of the total shipbuilding mobilization base.

Several of the major issues of productivity improvement and business conditions are common to suppliers and also shipbuilders. In other instances, improvements such as modernization of production management systems and increased use of modular design and construction techniques are contingent on closer integration of suppliers into the shipbuilding process. These facts and interactions have been stressed throughout this report. This section assesses several other supplier related issues, which concern the effect of Navy policies and procedures on shipbuilding suppliers.

DEALING WITH DIFFERENT BRANCHES OF THE NAVY

Rules and policies of the Navy change from time to time in response to internal and external conditions. The changes radiate unevenly throughout the Navy system, to prime contractors and to suppliers.

The supplier and the shipbuilder have to contend with different requirements of the different branches of the Navy, including the surface navy, the submarine navy, the nuclear navy, and the operating navy which do not always act in concert. Each has its own standards, regulations, inspection and documentation requirements, and mode of operation. The shipbuilder is required to satisfy each of these different branches, and, in turn, to communicate each of the their standards to its suppliers. The supplier's problem is further compounded by the fact that prime contracts have different specification

effectiveness dates and different provisions regarding "grandfathering" of earlier revisions of specifications. At any one time a shipyard may be be building more than one class of ship under different prime contracts, each with its peculiar specification baseline. Suppliers, similarly, may be involved with more than one program. The profusion of specifications with different applications and effectiveness dates causes monumental administrative problems in defining which material can or cannot be used on a given job. To be sure, each prime contract has an engineering change proposal (ECP) provision under which the shipbuilder or supplier may request approval to use earlier or later revisions of specifications. However, if different prime contracts and different classes of ships are involved, a separate ECP must be generated for each. These ECPs will be processed through different ship acquisition project managers (SHAPMs), and while approval may ultimately be granted, there are inevitable differences in time between the SHAPMs approvals. In the interim the shipbuilder or supplier is forced to manage duplicate parts in inventory and to use alternate parts at his own risk to keep material and production flowing.

The disparate requirements of the different branches of the Navy are not always in harmony. Furthermore, rule and policy changes may disseminate slowly. Following is a selection of representative problems of this nature that have been encountered by one supplier:

- o <u>Original Mill Certifications</u>. Transcribed certification had always been acceptable until January 22, 1982, at which time a decision was made that only the original mill certification would be accepted by the government. This policy change was not communicated to suppliers, or to the local offices of the Defense Contract Audit Service. Furthermore, no grandfather provision was made for shipments already in the system. Consequently suppliers incurred many reports of discrepancies because shipments supplied to the old standard were inspected for acceptance to the new standard.
- o <u>Specialty Metal Clause</u>. Beginning in October 1982, a defense acquisition regulation which excludes buying from NATO/SEATO countries began to be enforced. This occurred at a time when many U.S. steel mills were either closed or on reduced hours. Distributors carried larger inventories of foreign raw material and fasteners then of domestic suppliers, consequently components had to be made from raw U.S. bar stock if and when it could be found, at a substantial increase in delivery time and cost both to the government and supplier.
- o <u>ASNT-TC-1A 1980 vs. MIL Std 271E</u>. The military standard states that personnel must meet the American Society of Nondestructive Testing requirements which call for recertification every 3 years based on performance. Special interpretation of the military standard indicates that personnel must be completely requalified every 3 years. Despite its implications for suppliers' quality systems, the interpretation has not been formally documented and few suppliers or government

people are aware that a change in requirement has occurred as a result of a change in interpretation.

- <u>Outdated Specifications and Military Specification (MilSpec) Revisions</u>. Suppliers receive contracts from naval activities and shipyards for identical material, yet each may have the supplier working to different editions of the same specification or standard. This is caused by invoking the effective date of MilSpecs in a ship's specification. In later years, the MilSpec may be changed, while the ship specification is not. Naturally, vendors of equipment or material, whose configuration is governed by MilSpecs, tune their operation to respond to the latest Milspecs, while equipment for ships is procured in accordance with ship specifications. This practice is very confusing. For a supplier to take exception and be allowed to work to updated versions of the specifications, a deviation or waiver request must be submitted and ordering of material must be delayed until the waiver is granted. Exceptions to allow working to the latest editions of specifications are frequently not approved which presents a major problem when the item is a supplier's standard product made to the latest edition of applicable specifications.

It is essential that suppliers and shipbuilders stay abreast of current requirements and interpretations. Similarly, it is essential that the policies, requirements, and procedures of the different branches of the Navy be in harmony to the extent possible. Yet, there are few formal mechanisms for addressing either area. Of the two problems, that of potentially conflicting Navy requirements appears the most difficult to address. The Navy could assist contractors in having up-to-date technical requirements and data by publishing a monthly list of pertinent regulatory and specification changes, and by improving the completeness and responsiveness of its technical documentation center.

A related problem is the extent to which the Navy complicates its procurement by specifying certain unique products when commercial equivalents are available or when the Navy specifications lags the state of the art. For example, MilSpec MIL-B-18558 for radial shaft bearings limits the allowed load to no more than 75 psi. Until about 40 years ago, this was appropriate. Current technology is such that today's bearings can and--in the commercial market as well as other nations' navies--do handle loads of two to two-and-one-half times that figure. However, to meet the specifications for U.S. Navy applications, suppliers must provide a bearing surface at least twice as large as is actually needed. With the additional housing size and manufacturing time, this extra cost is actually multiplied throughout the manufacture. Such problems can be addressed through programs to update MilSpecs. Another way to address them would be through standardization of bearing sizes.

The problem of the different branches of the Navy extends beyond the requirements that suppliers and shipbuilders must meet to the

Navy's organizational structure for managing technological change. Within the NAVSEA organization, there is no single focus for production technology development or productivity improvement. New equipment or production processes are introduced through the responsible technical code or by an engineering change proposal. If a technical code wants to sponsor the development of new equipment for the fleet, it must present its case for research and development (R&D) funding under that particular code. Depending upon the presentation and the situation, R&D funding may or may not be forthcoming. A contractor or supplier that initiates an engineering change proposal must also go through a tedious approval circuit. (Similar constraints to innovation may be encountered in any large organization.)

Continuity of personnel or the lack of it affects relations between suppliers and the Navy, and the problem of the different branches of the Navy. U.S. naval officers rotate assignments every 2 to 3 years. Some officers, especially engineering duty officers, develop a depth of knowledge of ship design, and construction and repair. The extent of knowledge of naval personnel, and the continuity of their service with the Naval Sea Systems Command (NAVSEA) and with particular projects affect the promulgation, interpretation, and enforcement of requirements.

COMPETITIVE PROCUREMENT VS. STANDARDIZED PRODUCTS

Navy procurement goals include maximum standardization to simplify engineering and reduce support costs, and also an emphasis on competition to obtain a fair price. The policies of competition and standardization are occasionally in conflict; there are advantages and disadvantages to each.

Standardization[2]

The advantages of standardization are widely touted and pursued. From the standpoint of ship components, standardization enables competition on the initial purchase. It avoids or minimizes a number of types of costs--those associated with qualification of new equipment, with publishing and maintaining more than one set of technical documentation to support a system (e.g., technical manuals, provisioning data, and training publications), and with training personnel to operate and maintain more than one vendor's equipment. It also simplifies logistic support. Prime contractor direct labor to install and test systems for follow ships is reduced, as are costs for supplier support services and tests on follow ships. Standardization also minimizes interface

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[2] The National Shipbuilding Standards Program is described in Appendix C and assessed in Chapter 8.

problems between systems and system-to-ship support systems, thereby reducing prime contractor direct labor associated with design changes, configuration management, and installation.

On the negative side of the ledger, standardization can reduce competition, thereby narrowing available or alternative sources of supply. Standardization makes negotiation of fair and reasonable prices for follow-on equipment difficult since the selected source for class standard equipment realizes that the U.S. Navy, and subsequently the contractor, will pay for standardization. Therefore, incentive to reduce or control costs is lost.

Standardization can also repress the potential for better designs and the ability of the U.S. Navy and the contractor to advance the state of the art. Occasionally, state-of-the-art equipment is available at a lower cost than designated class standard equipment.

Standardization sometimes works against supplier interests. Not only may a supplier lose a market niche that it has invested much effort and capital to develop, but the winner of a competition to supply a standard product may not be the company that took the risk to fund the R&D and develop a product in the first instance.

Competition

Promoting competition is required by the Competitive Procurement Act of 1984. A competitive environment provides reasonable assurance that prices quoted are the lowest available. Competition eliminates potential for price gouging on follow-on equipment and reduces the need for extensive cost and price analysis to justify price. Competition also expands the base of suppliers available to meet production in the event of a national emergency.

There is some risk, however, in a competitive environment of obtaining a technically inferior product. Increased time and resources need to be provided to procurement for technical review, and facility and quality surveys. There will be increased costs incurred in developing procurement specifications and soliciting and evaluating proposals. Some post-award costs could be avoided if equipment were purchased on a single source basis.

Competition vs. Standardization

It is evident that, while the Navy is required to seek both competition and standardization, the two objectives can work against each other. From a product standpoint, standardization is desirable; from a cost standpoint, competition is sought. The balance between these objectives is established by the Navy in the terms of the shipbuilding contract.

To maintain standardization and at the same time realize the benefits of competition, the Navy could purchase from manufacturers a procurement specification with drawings and component source lists sufficiently detailed to enable competition on subsequent orders. The

advantages to the Navy of this approach are that it removes the original class standard equipment manufacturer from sole or single source category, yet it preserves the incentive for the original manufacturer to control or reduce costs to remain competitive. The disadvantages include the fact that it will increase software cost for initial class standard procurement and add logistics costs as a result of selecting a new supplier.

Competition should be used in the initial buy of the major system. Simultaneously, options for follow shipsets should be obtained. A testing of the market prior to rebuy or option exercise will determine that the price is fair and reasonable.

As standardization is achieved, competition will be possible through open bidding among suppliers for those standard items. Considering the best interests of the U.S. Navy, the advantages of initial standardization outweigh the benefits of possible premature competition. The additional efforts which must be expended through either (1) negotiating fair and reasonable prices on follow-on equipment, or (2) establishing standardization of components, will be repaid through the savings resulting from these procedures.

RIGHTS IN DATA

Suppliers historically have been accorded different degrees of protection for their engineering data, depending on the circumstances. On one end of the spectrum, patented products are accorded general comprehensive protection under U.S. patent law. At the other end, engineering data on products developed with Navy funds are generally public information (unless classified--classification is rarely invoked on hull, mechanical, and electrical equipment). For their part, suppliers seek to protect their manufacturing data and know-how under a proprietary cloak. The Navy, however, is required by law to increase competition and to reduce the cost of spare parts. Thus the Navy has a built-in incentive to make engineering data available, including that classifed as proprietary, as an aid to competition.

The suppliers' rights in data protection is stipulated in federal acquisition regulations, which address a number of situations. Where items are developed at government expense or where the government has indemnified the supplier against risk, the Navy obtains rights to information allowing competitive bidding for replacement units and parts. Where standard commercially available components have been incorporated into a supplier's proprietary product, and to which no value has been added, the Navy is entitled to information allowing replacement part purchases from the original source. Products developed at the supplier's expense and risk represent proprietary items involving significant investment, the recovery of which is planned over time and in the sale of replacement parts.

The rights in data regulations were designed to protect the confidentiality of the supplier's engineering data when proprietary data is in government hands. The rights in data regulations clearly address the above situations, and yet there are many instances in which

proprietary engineering data in the custody of the government were made publicly available, thereby negating the legitimate proprietary advantage of the supplier, and often negating a considerable development investment on the supplier's part.

As a result of congressional action, federal rights in data regulations are to be changed to promote competition, among other purposes. In the committee's view, any deviation from legitimate, protected vendor rights in data provisions ought to be the result of negotiated agreement, where the Navy purchases such rights or provides other compensation.

NEW PRODUCT DEVELOPMENT AND QUALIFICATION

Product improvements are implemented slowly in shipbuilding programs. Shipbuilding designs take years from inception to completion and the resulting shipbuilding construction contracts may be authorized over numerous fiscal years. For example, the basic engineering of the SSN 688 Class attack submarine was done from 1965 to 1970. Current Navy planning calls for 688 Class ships to be awarded and built through fiscal year 1990. A fiscal year 1990 ship, delivered to the fleet in 1995, may be outfitted with 25- to 30-year-old equipment designs. Those same ships will be operating in the year 2015 with some 45 to 50-year-old designs.

In addition to the longevity of the ship class design, Navy efforts standardize its fleets and simplify logistics, maintenance, and operation also limit the shipbuilder's and suppliers' ability to introduce new products. Standardization provisions are invoked in shipbuilding contracts and subcontracts to reduce life-cycle costs through common training and provisioning requirements, and so forth. Standard products also result in repetitive procurements.

The other side of the coin is that the repetitive procurements often are directed at a single, special source and equipment designs are perpetuated for decades. The standardization may increase costs through reduced competition and also stifle design and product improvements. The case study of quiet bearings in Appendix B fully explores and supports both these points.

In those instances where the Navy has permitted shipbuilders and suppliers to introduce new technology developments into established, standardized designs, product and quality improvements and significant cost savings have been achieved by all parties. The following two examples from the SSN 688 Class attack submarine program illustrate how departure from or updating of standard designs, without major design impacts, can result in product improvements and cost savings.

The SSN 688 Class design originally used HY-80 steel castings for numerous hull inserts. The selection of castings for these applications was influenced by their size, technical considerations (i.e., configuration and strength), and low cost. (Castings are typically cheaper than forgings, particularly where small quantities and complex configurations are involved.) The HY-80 castings were plagued by problems of hydrogen embrittlement which required significant amounts

of weld repair both at foundries and in the shipyards. These repairs resulted in extensive schedule slippages and rework costs. In an effort to obviate the hydrogen-embrittlement problem, one shipyard elected to substitute forgings and weldments for the castings on a subsequent construction contract for 11 ships. The 11-ship award made the normally more expensive forgings cost effective since the forging die costs could be amortized over a large number of units. The forgings and weldments, also precluded the weld repair problem, significantly reducing schedule delays and rework costs.

NAVSEA assisted the shipbuilder by funding the design agent to review the technical feasibility of the change and incorporate the alternate configurations into the ship design. The net result was signficant cost savings on the 11-ship program and improved product quality. The switch away from castings also had another beneficial impact in that it spurred the HY-80 foundries to upgrade their facilities through the addition of larger argon-oxygen decarburization furnaces. These new furnaces have dramatically improved product quality and lowered the product cost by improving the quality of the castings and thus reducing the amount of weld repair. As a result, the castings are once again cost-competitive.

The other example concerns hydraulic control valves. There are 231 ship service hydraulic control valves in each 688 Class ship, with a total value of approximately $800,000 per ship. Design, quality, and delivery problems were experienced by the shipbuilders on the early hydraulic control valve subcontracts. Because of those problems, one shipbuilder attempted to develop competition for the valves on later shipbuilding contracts. After competitively bidding the original source against its principal competitor, the shipbuilder awarded a contract to the competitor on a low-bid basis. The low bid was made by the competitor in spite of the fact that his proposal included nonrecurring costs for design work and qualification testing. In this instance, the cost of incorporating the new valves into the Class design, about $750,000, was borne by the shipbuilder. In return, however, the shipbuilders and NAVSEA have enjoyed the benefit of competition for the hydraulic valves on all subsequent 688 Class ships. While total savings that have accrued to the shipbuilders and the Navy as a result of introducing competition are not known, they are undoubtedly significant, as the two suppliers have continued to compete for (and share) the valve market.

These two examples illustrate the advantages of introducing new products and competition into shipbuilding. In both instances, product and quality improvements and significant cost savings were achieved. The Navy has been the direct beneficiary of those product improvements and savings. In the case of the hydraulic control valves, the Navy will incur some additional cost in provisioning a second set of valves; however, those costs will be minimal compared to the hardware savings that have been achieved. In the case of the substitution of forgings and weldments for castings, there have been no costs borne by the Navy other than the initial cost of incorporating the alternate configurations into the ship design.

From the supplier's point of view, the whole naval procurement process weighs heavily against supplier-initiated change. Shipbuilders are reluctant to initiate changes on behalf of suppliers because they have fine-tuned their drawings and manufacturing systems to maximize production efficiency. For their part, suppliers know that any change in material will be perceived by both the Navy and the shipbuilder as a major disruption. As a result, after the initial procurement competition, the engineering of subcontracted items tends to be locked in by the inertia of the program. Not only must a supplier with a better product or idea overcome the inertia, but no clear channel exists through which to communicate. The supplier is left to his own devices.

The Navy should consider adopting a policy that promotes competition and flexibility among shipbuilders and suppliers, while not compromising the objectives of product standardization and performance. This would be particularly advisable in those situations where a significant number of ships are being produced to a common design over a long period of time. At a minimum, when the Navy expects to perpetuate a single class design over many fiscal years, it should consider an upgrade of the design midway through the program. This would enable a review of all major equipments to ensure a technological update of the design and a competitive cost.

7

CROSS-CUTTING ISSUES AND NEEDED DEVELOPMENTS

SHIP PRODUCTION TECHNOLOGY

Computerization

The high labor content of shipbuilding and consequent low value of shipments per employee in the shipbuilding and repair industry is a matter of grave concern. Technology developments have been described and assessed that reduce the labor input to shipbuilding, through application of modern logic (i.e., zone-oriented ship construction) and also through computerization. Zone-oriented ship construction has already been discussed in detail. From the Navy's standpoint, in addition to making the industry more competitive and thus addressing the problem of inadequate demand, computerization offers the opportunities of lower cost and management efficiencies. The following discussion highlights needed developments in this area.

CAD/CAM Data Base

Integrated computerized systems have been found by many companies to improve productivity. One definition of integrated design and manufacturing would be a system which embodies a free-flowing stream of data able to support all functions throughout the organization and during the life of the product.

Two developments in naval shipbuilding are needed to provide the technical basis for integrated computerized systems. The technical specifications need to be established for an engineering data base for shipbuilding; and data base systems for handling and communicating engineering and geometric data are needed.

Common Engineering Data Base As described in a previous section, every ship has an engineering data base in the form of drawings and technical references, and there have been some attempts to convert ship engineering data bases to electronic format. Economies will accrue when these efforts succeed, but to be successful it is necessary to start with the basics. A generic specification is needed for a ship product definition data base, as a basis for computerization. Such a data base would begin in the preliminary design phase of a project and would provide a foundation for all engineering activity including

design, production planning, production, logistics, maintenance, repair, and overhaul. The Navy, as the major shipbuilding customer in the United States, and as the originator of the ship design data, is in an outstanding position to cause or foster the rapid development of such a data base, in conjunction with the shipbuilding and supplier industry. The generic specification would be in the nature of a standard for the creation of shipbuilding engineering data bases in a format suitable for computerization.

Data Base Systems Along with the specification for a common engineering data base for shipbuilding, data base systems are needed for handling and communicating diverse engineering data including geometric data and data on configuration control, specifications, material requirements, part numbers, assembly numbers, and tolerances, as well as all of the data required for production scheduling, tooling, and planning, in all of the activities in conceiving, producing, delivering, and servicing the product. While the problem of the common engineering data base needs to be addressed by shipbuilders, data base systems development is being undertaken by many companies, which are trying to integrate computer systems that were originally developed as batch systems with many data bases. The Naval Sea Systems Command (NAVSEA), as well, has an effort of this type under way (i.e., Computer-Supported Design Program). The shipbuilders can possibly take advantage of the advances of others in their systems modernization efforts.

Computer Graphics Systems

Computer graphics systems have developed very rapidly in recent years. This technology has changed so much that leading industrial companies consider a system old when it has been in use for 5 years. Most of the shipbuilders' graphics systems appear to be of an age that modernization should be given serious consideration.

Modern systems are capable of much more sophisticated use than simple drafting, which is the predominant use made of them by most shipbuilders today. With modern computer capability, the Navy could complete preliminary design on computer systems and transmit the data in electronic form to naval architects and shipbuilders. This computer graphics capability could be the foundation for an on-ship system that would support maintenance and overhaul operations with up-to-date information.

The volume of data required for shipbuilding is very large but not as well defined as are the aerospace requirements. It would appear that there could be advantages in having computer systems tailored to the future needs of ship design. One approach to getting the best hardware and software for the total job would be to turn the task over to a joint industry and Navy task force.

Computerization of Ship Design and Configuration Records

Ships typically have the longest service life of any military vehicle. With this long life comes the problem of maintaining records of the construction and systems configuration. In the past, this has been done with a very large number of drawings and documents. This documentation is hard to maintain. After many years of service it is often necessary to make actual ship checks to determine true configuration. In times of emergencies, this lack of timely information can slow up the repair or overhaul. With the computer graphics capability available today it is possible to have a computer on the ship and a computer on shore with the most up-to-date information on actual ship configuration. Provided the systems and software are compatible, data can be transferred between computers to insure that both sets of data are up-to-date at all times instead of having drawings in two or more locations that are very difficult to maintain. With computerized up-to-date information, it becomes more practical to prefabricate ship structures and systems in preparation for repairs upon the return of the ship to port.

Ship Design, Construction, Operation, and Repair Data Transfer and Control System

Today the foundation for data communication in Navy ship construction is the drawings and documents that start in the Navy preliminary design effort. Each organization revises and adds to this data. Organizations that use computerized systems have to make their own interpretation of the drawings and document data and enter it into their own data base. The continual reinterpretation of the data introduces errors and adds labor. It is recognized that drawings serve as a valuable tool for visual communication of data for people in a shop environment. However, advanced computer systems are much more efficient at the accurate transfer and storage of design data between Navy preliminary design, the naval architect, and the shipbuilder. The Navy and industry need to develop the capability of using electronic data as the standard for data transfer instead of requiring drawings. A joint Navy, design agent, shipbuilder, and supplier effort is needed to define the requirements, develop plans, establish standards, and organize the effort so that electronic data can be used for future data transfer between the Navy, its ship designers, lead and follow shipbuilders, and suppliers. While the Navy will establish the data transfer and control system including software, industry will use the system and its data in every phase of its operations. Therefore, both interests have to be in fundamental agreement with the system. This can be achieved if the Navy undertakes development and implementation in conjunction with industry and not independent of it.

Design and Production Methodologies

Impact of Zone-Oriented Ship Construction

Group technology is used in much of industry to classify and code parts so that they can be produced most efficiently in limited quantities. Similar kinds of parts are treated as if there were larger batches with improved production costs. This same philosophy is being applied to shipbuilding in the form of zone-oriented construction.

To adopt zone-oriented construction technology, the entire ship design must be virtually complete before production can be efficiently started. In the past, construction would be started before much of the systems work would be finalized. Using zone construction methods, the structure and related systems have to be designed completely before the units can be started through the fabrication and assembly process. This method of construction requires that all design details of systems (e.g., holes and supports) be defined at the time the structure is started. These production methods require a much larger engineering effort at the beginning of a program. While the total engineering man-hours could increase, experience to date indicates that the additional engineering man-hours will be more than offset by a significant reduction in production man-hours resulting from accomplishing the production work much more efficiently.

The transformation of U.S. shipbuilding practices to zone-orientation is under way in every shipyard building naval ships, and is clearly in the Navy's interest. Improvements to date have been ad hoc, based on each shipyard's pursuit of its own objectives, obtaining Navy concurrence and support on a problem or project-specific basis. The needed developments to take full advantage of zone-oriented shipbuilding methods are described in Appendix A, in the findings of the Work Group on Integration of Engineering and Production.

Factoring Producibility Considerations into Ship Design

The Navy is acutely aware of the effect of producibility on cost and knows that it is essential to take the subject of producibility into account in the ship design process. It is not sufficient to leave producibility considerations to detail design, which is undertaken by the shipbuilder or his agent, because the timing of this phase, after the ship design is well advanced, necessarily limits the extent of producibility considerations.

Since every shipbuilder's production methods are somewhat unique (because of facilities and technologies employed), the ideal producibility input would be for the shipbuilder to participate as a full-fledged member of the contract design team. However, the extent to which the Navy can obtain producibility input in design is constrained by the possibility of anticompetitive practices. A technique which the Navy has employed quite successfully is to convene a group of shipbuilders to critique the producibility aspects of the Navy contract design. This has been done on an ad hoc basis, through one or more

design review meetings of shipbuilders and suppliers convened by the Navy. Recently, the Navy has carried this approach somewhat further. For the DDG-51 contract design effort, the Navy established a producibility task force of prospective shipbuilders to contribute throughout the contract design effort.

In comparison to most industries, the ship design process is structured to have very little input from the people that will build the ships. The contrast with the aerospace industry is striking. In aerospace, a manufacturing team is placed in the engineering design area on a full-time basis during preliminary design. It is at this point that many of the design trade-offs are made that seriously affect future production costs for structure and systems. Furthermore, the designers are provided with certain producibility and cost reduction guidelines and aids. Particularly helpful in this respect are manufacturing cost and design guides. In the aerospace industry, these guides were developed by the Air-Force led, industrywide Integrated Computer-Aided Manufacturing (ICAM) program. In easy-to-use formats, these documents provide designers with manufacturing cost data for different products and methods, based on industrywide practice.

The guides enable the user (i.e., design, manufacturing, and procurement personnel) to make quickly the trade-offs necessary to achieve lowest acquisition cost with confidence. These manufacturing cost design guides as well as the documented standards can help aid the engineering designers develop more producible designs. Comparable design aids based on industry-wide experience would contribute to more cost-effective naval shipbuilding.

Expert Systems and Artificial Intelligence

The technology of gathering data and making decisions using the data is changing with further evolution of computer systems. Expert systems are evolving. Expert systems collect and employ the basic knowledge and heuristics of decision making of the experts (such as production engineers). These systems can be used in the future to support the ship design and production decision-making process.

Artificial intelligence is the next logical step beyond expert systems. Systems employing artificial intelligence gather experiential data resulting from their use, and then, based on experience, change the heuristics of the decision-making process.

<u>Production Methods Advancement</u> A great deal of investment and research and development (R&D) has been undertaken to advance ship production methods, and some productivity improvement has been realized. Some innovations have resulted from industrial R&D and investment; for example, automated land-level facilities for the fabrication of submarine hull sections which have cut man-hours in that construction phase by half. Other innovations have been spurred by government programs, e.g., the application of zone-oriented construction methods.

Many other technology developments have been made, including improved cutting, welding, forming, automatic pipe bending, and alignment systems. These and other methods improvements incrementally improve shipbuilding productivity.

New technologies continue to emerge that can improve productivity if they are applied. Three areas that warrant special consideration are accuracy control, robotic welding, and flexible manufacturing systems.

Accuracy Control Adoption of zone-oriented shipbuilding methods creates opportunity for applying statistical control of manufacturing operations as a means of achieving constant improvements in productivity (Chirillo, 1982a). At least two shipbuilders already collect prerequisite data for hull construction of warships, including aircraft carriers, surface combatants, and submarines.

Statistical analysis of accuracy variations of a shipyard's current work processes can be used to predict how accurate hull structure will be in a ship never built before. Abilities to withstand high-impact shock are directly related to accuracies achieved without forced fitting during construction processes. Maximum submergence depth of a submarine is related to the degree of hull circularity achieved and absence of locked-in stresses. Thus, the Navy's possession of statistical evidence of accuracy from shipyards before award of contracts would serve military requirements.

As quality and productivity are directly related and since accuracy control provides an analytical basis for less direct inspection, there are prospects for savings by both shipbuilders and the Navy. The Navy, its shipbuilders, and suppliers need to further develop statistical control of manufacturing.

Robotic Welding Robotic welding is being developed rapidly in many industries. This should enable shipbuilders to take advantage of developments from other industries. It appears that, in shipbuilding, there is a large amount of welding that could be done by portable robotic welders. Zone-oriented construction provides access for crane positioning of portable welding robots and the automatic welding of many joints that previously could only be welded by hand. Portable robotic welders could be moved into position, the welding head run through the teach sequence, and then the welding operation performed. Some people believe that this type of operation might not be successful until there is off-line programming capability, therefore some development work needs to be done to determine the process limitations.

In recognition of the fact that there is no commercially available portable welding robot on the market that will satisify the unique requirements of the ship construction process, it should be noted that the Society of Naval Architect and Marine Engineers' (SNAME) Ship Production Committee technical panel on welding has initiated a National Shipbuilding Research Program project to develop a definitive technical specification for a portable shipbuilding robot.

Flexible Manufacturing Systems The trend toward zone-oriented methods and the integration of engineering planning and production functions in support of them is an element of a larger trend in the shipbuilding industry towards flexible production systems. As opposed to high volume, standardized production, flexible system production focuses on production processes that are change oriented and which suit the production of varying end products in low volume. Employment of a product-oriented work breakdown structure is enabling shipbuilders to exploit the principles of group technology for producing the many interim products typically required for each ship in varying quantities.

Flexible manufacturing systems are being introduced in many industries to take advantage of group technology for the production of limited quantities of parts. Flexible manufacturing systems are a collection of machines or processes that are set up to very efficiently process a specific type of part. The most popular example would be a flexible machining cell set up with a robot at the center as a part-handling device to move parts from one machine to another. These cells are usually set up with several kinds of machine tools that have automatic tool changers so tht the tools can be rapidly changed as the different parts are processed. Similar parts can be rapidly processed through this type of facility. This same philosophy can be applied to shipbuilding if proper consideration is made in the design. Examples of potential applications in shipbuilding would be machined parts, systems structures fabrication, welded subassemblies, and any type of part that must go through the same processing steps.

Naval Ship Design Process

A number of long-term developments are affecting the naval ship design process overseen by NAVSEA. For a decade or more, NAVSEA has relied increasingly on consulting design agents for support in conceptual and contract design work. While this strategy has certain advantages of efficiency, it complicates integrating lessons learned from operating experience into the design process.

Another trend is the increasing relative importance, in terms of value-added, of the combat systems suite over the ship platform upon which it is installed. This increases the prospect that such fundamental naval architectural considerations as weight, stability, safety, and seaworthiness might be overridden by mission performance considerations in the design and construction process. This situation points up the need for more effective communications and interaction between the design and production of the combat systems suite and the design and construction of the combatant ship. A positive development in this area has been the establishment of ship system engineering standards, which will enable change of combat systems without costly, unforeseen alterations or disruptions.

The naval ship design process is being transformed by the use of computers for calculations, graphics, and data retention and exchange. NAVSEA has the explicit goal of moving from a paper-based

design and acquisition process to a computer-based process. Achieving this goal will necessitate far-reaching changes in information systems, and in the skills of those who use them. There are technology development and capital investment implications to the changeover as well.

As shipbuilders apply zone-oriented construction techniques to naval shipbuilding, it becomes increasingly important for the Navy to stress design for production in its naval ship design process. A number of different steps have been taken by the Navy to ensure that naval designs are producible; much more needs to be done to take full advantage of potential productivity improvements.

Given the long-term trends that have been bearing on the ship design process, it may be timely to conduct a review and assessment of the naval ship design process as overseen by NAVSEA, with the objective of describing that process and analyzing the technology, policy, and other trends that affect it.

Shipbuilding Standards Development

The U.S. naval shipbuilding industry is improving the efficiency of the ship design and construction process by applying high technology. Most naval shipbuilders are moving toward automated design and production capabilities. There is a lot more to achieving real productivity improvement, however. A critical need exists for improved coordination and for an integrated procurement and production system in the shipbuilding process. Standardization can help the industry meet these needs.

Standardization is vital to improving productivity in most industries, particularly the shipbuilding industry. The effectiveness of the technology improvements, computer-aided design and manufacturing, accuracy control and numerically controlled production machinery all depend on standardization. Standardization must also be applied to the shipyard procurement process. Uniform, effective, and acceptable industry standards are needed which can be used by designers, shipyard purchasing departments, suppliers, and shipyard production personnel in the planning and production of the ships they build if improved efficiency and cost reductions are to be realized.

The National Shipbuilding Standards Program (see Appendix C) is beginning to fill the need of the U.S. shipbuilding industry for a uniform and effective set of industry standards. It is a complex and difficult task which can be completed within a reasonable time through a coordinated effort which is already under way. The example and proof of benefits are demonstrated in the successful shipbuilding standards programs of other countries, and the role of standardization in their international competitiveness.

Many shipbuilding nations around the world have already developed significant numbers of shipbuilding industry standards within their own countries. Most prominent among these are Japan, Great Britain, Germany, and Sweden. The International Standards Organization (ISO), through its marine subcommittee TC-8, has developed a significant number of international standards for shipbuilding. The U.S.

shipbuilding industry, including the naval shipbuilding industry, cannot afford to ignore the benefits achieved and methods used by others in developing and applying shipbuilding standards. A special task group of ASTM F-25 was formed in the spring of 1983 to look into the potential for converting other countries' national shipbuilding standards to U.S. standards. A new ASTM subcommittee was also created to participate in the activities of the International Standards Organization's Committee TC-8 on shipbuilding and to help the U.S. shipbuilding industry benefit from the work performed by the other participating nations. These nations have shown us the way. Their standards programs are well established with proven benefits and the standards themselves are readily adaptable to the U.S. shipbuilding industry. A change in course in the U.S. standards development effort, to use, to the extent feasible, foreign or international standards, which have already been developed and proven, as the technical basis for U.S. national shipbuilding standards, including the revision and updating of MilSpecs, would minimize the effort needed to develop a comprehensive set of U.S. national shipbuilding standards.

INDUSTRIAL MANAGEMENT AND PRODUCTIVITY

Of the many determinants of productivity in any industry, the quality of industrial management is nearly always one of the most important and influential. Because shipyards are not integrated supply and production facilities, but rather are facilities for fabricating the hull and assembling systems from thousands of sources, the coordination of the ship production process is a classical test of management expertise. It is an especially difficult job that requires the highest degree of management skill, technique, and planning. Furthermore, this will become even more important in the future. To become more productive, shorten lead times, and improve the product, shipbuilding information systems must grow more integrated and communications between the Navy shipbuilders and suppliers will have to be intensified and concentrated. For these reasons, the shipbuilding and supplier industry requires as sophisticated and professional a management capability as any U.S. industry. This section focuses on industrial management's many impacts on productivity.

Key Elements of Industrial Management

Industrial management consists of those managers in the production or manufacturing firm whose responsibilities are focused on making the product. It typically includes the corporate officer in charge of the overall manufacturing function and managers at all levels involved in the functions of production operations; scheduling, production control, inventory management; purchasing, procurement, subcontracting; production/manufacturing engineering; industrial engineering; quality assurance, quality control, inspection; industrial relations and personnel; and, cost control and cost accounting.

The activities of these managers include both long-term policy or structural planning and decisions and shorter term, operational functions. Both the long-term and short-term activities are equally important. However, in most companies the short-term operational sector receives the bulk of management attention. This is normal, of course, because pressures for daily, weekly, and monthly accomplishments in the form of schedule commitments, cost objectives, and coordination demands in production operations are real and constantly demanding. Things break or get lost or are rejected by inspection, due dates are missed, parts or assemblies must be expedited, and one emergency follows or indeed often creates another. These regular crises, minor and major, set aside or postpone attention to the longer-term strategic issues which always exist, whether or not they receive attention. Furthermore, the sins of poor operations are at least more self-evident and generally more quickly correctable than the omission of competent strategic planning to properly position the productive capabilities of the organization. For these reasons, compounded by the general absence of effective manufacturing strategy in much of U.S. industry, the next section focuses more on manufacturing strategy than on operations.

Effects of Strategic Planning on Productivity

Outstanding industrial management can usually accomplish productivity gains of only 20 to 25 percent through such ongoing operating improvements as better housekeeping, discipline, supervision, training, work methods, and attention to detail. In contrast, the truly large productivity gains are generally derived from structural changes such as major innovations in equipment or process technology and basic changes in manufacturing approaches. When an industry is seriously noncompetitive, as is much of the U.S. shipbuilding and supplier industry relative to many foreign producers, critical attention needs to be paid to strategic structural areas. These areas include: make vs. buy; capacity level; number of facilities; size of facilities; location of facilities; choice of equipment and process technologies; production planning, scheduling and control systems; formal organization of manufacturing; cost controls; work force and human resource management; and quality assurance and quality control.

How should these structural areas be analyzed? What is the analyst looking for? For competitive effectiveness, each of these sets of structural decisions has to fit together into a consistent whole, a manufacturing entity totally designed and operated to meet the strategic, competitive needs of the enterprise.

This sounds simple and it can be. But it does require, first of all, that the competitive strategy of the enterprise which the productive unit is intended to serve is defined, for without that the criteria upon which the performance of the productive unit is judged are usually full of conflicts and inconsistencies.

Seven or more criteria are typically present. Each criteria selected to be the most critical and essential for competitive success would demand a very different set of structural decisions.

These conflicting criteria are: cost, quality, delivery cycle, delivery reliability, flexibility for product change, flexibility for volume change, and capital investment requirements.

Obviously, all seven are nearly always important. What is fundamental to their use as design criteria, however, is they represent trade-offs in manufacturing system design, just as size, weight, maneuverability, and combat capability are trade-offs in naval ship design. The expertise of management determines how successfully the productive unit as a whole can be designed and operated to accomplish the maximum on the few most critical criteria or combination of criteria while giving up the least on the others.

These structural decisions by industrial management are not only critical to meeting stragetic objectives, but they are long-term in nature. Therefore, they take years to change if they are made "wrong" in the first place. Equally important, if operating managers are saddled with the wrong manufacturing structure, such as too many facilities located in the wrong places, no amount of industrial management effort, or plant technology upgrades, can make the unit perform as a competitive resource.

Saddled with such disadvantages, plant managers can only take an active role in the surfacing of structural problems and developing and implementing with top management a competitive strategic manufacturing plan. In such a structure each element of the system is designed, shaped, and honed so as to be consistent with and supportive of all other elements such that the production facility is focused to accomplish the mission demanded by the strategic objectives and plans of the company.

Focus can be powerful, and the absence of focus is debilitating. Nevertheless, well-focused production facilities are the exception because of the prevalence of myopic economic analysis which disregards the realities of spreading management, engineering, and work force expertise too thinly over too many markets, products, and technologies, as well as (especially relevant to naval shipbuilding) degrees of quality and tolerances, and levels of demand.

The strategically structured and focused plant, while less complex and much easier to manage, demands discipline, attention to operational detail, and day-in day-out execution to carry out its competitive mission. The abilities, morale, and determination of the plant management and work force have an enormous influence on the productivity and effectiveness of the facility. The newest equipment, the best technology, and unlimited capital investment are to no avail without the management and work force which operate the facility and turn out the product. In these ways, industrial management is an essential and critical ingredient in shipbuilding productivity.

Industrial Management and Technology

Of the choices that go into a production facility, the ones involving equipment and process technology probably are the most important because they lock in many of the strategic aspects of production (i.e.,

land, labor and capital requirements). The equipment and process technology are closely intertwined with product design. The product can be designed to make it easier and cheaper to make. The days of design engineering isolation and independent authority are ending in better-managed companies. While still existing, the old time practice of "throwing the bundle of blue-prints and specifications over the wall" between the engineering and manufacturing departments is becoming increasingly rare. This is especially true in shipbuilding, where design for producibility is a major factor in the ultimate cost of the ship. This is an organizational problem; one more sector where management policies and procedures make all the difference. In naval shipbuilding, addressing the issue of design for production requires sophisticated management and close cooperation on the part of Navy and its shipbuilders because the originator of the design, the Navy, and the shipbuilder, are separate organizations.

Productivity Programs

Many outstanding U.S. manufacturing firms have reacted to the loss of their competitive edge with productivity programs which seek to restore continuous annual productivity gains. Research into these programs suggests seven criteria which are nearly always important in their success:

- o Top management interest, support, involvement, and direction.
- o Positive attitudes on the part of workers and labor organizations.
- o Department and plant projects developed from the bottom up (in contrast to top-down imposed programs).
- o The formulation and use of demanding but realizable productivity improvement goals for each major productive unit.
- o The awareness and inclusion in plans and programs that "productivity" should mean more than labor efficiency and should be defined as output/input where input includes labor, overhead, materials, and capital.
- o The availability of expert staff assistance as a resource to be called upon and used by line managers (in contrast to placing direct authority and responsibility for productivity improvement on staff personnel).
- o A simple, understandable measurement system for regularly monitoring and reporting productivity results.

Successful productivity improvement programs tend to be broad in their purview and coverage. Instead of focusing on a limited cost area such as, for example, direct labor output, they set out a wide net for any and all changes which would improve overall plant productivity.

Table 14 describes the scope of effective productivity programs.

Although productivity programs, are of limited impact compared to changes in manufacturing structures and policy, their value is that: (1) good results can be obtained in a relatively short time (such as

TABLE 14 Potential Ingredients in Effective Productivity Programs

Manufacturing Engineering	Human Resource Management	Production Control
work methods	job content	scheduling
work simplification	recruiting	inventory management
tools, jigs, fixtures	selection	location/size of buffer and safety stocks
product design/liaison	job enrichment	-
motion study	working conditions	just-in-time inventory management
plant layout	training/development	lead times
materials handling	supervisision	order quantities
value analysis	compensation	set-up costs
work sampling	communications	level vs. chase
use of standards	benefits	logistics of supply and delivery

Operations	Quality	Procurement
housekeeping	specifications	value analysis of purchased parts and materials
maintenance	statistical QC	
organization structure	training/communications	vendor selection
reporting relationships	zero defects	
coordination	quality circles	bidding/pricing
performance measurement	field service reports	quality control
first-line supervision		delivery reliability

Cost Analysis
cost of goods sold
investment in capital assets
inventory carrying costs
depreciation
fixed vs. variable costs
overhead costs
materials
direct labor
engineering/R&D
ABC analysis
zero-based budgeting

6-12 months); (2) their use cannot only increase productivity, but, as for example in good housekeeping, usually induces improved morale, self-discipline, team spirit, self-respect, and confidence in management; (3) elimination of one source of low productivity usually reveals another, so that improved productivity often accelerates as problems are surfaced and eliminated one by one; and (4) operational changes, involved in productivity improvement, are less expensive and risky than structural changes, and until operations are "cleaned up" it is often difficult to appraise the need for structural changes accurately.

An attitude which focuses on continued productivity gains is more effective than setting up "productivity programs" when productivity levels off. For example, the Japanese record in shipbuilder and supplier productivity improvement has been brought about, to a large extent, by a management policy calling for "constant improvement" of every facet of product development and production. These improvements are tracked on a weekly basis. This has led to, or has been facilitated by, a remarkable degree of horizontal integration of all personnel involved in product design and manufacture, including suppliers. It has also evolved the highly effective "small group activities" (often labelled "Quality Circles" in the United States) which have promoting of a team approach to safe working conditions and product improvement as their principal purpose.

The Navy's Impact on Industrial Management

As the key customer and sometimes the sole customer for shipbuilding, the Navy has a substantial impact on industrial management and productivity. This impact is felt, of course, in the procurement and bidding process where price is a key factor and, therefore, efficiency and cost performance are highly motivated. After the contract is awarded, however, the Navy has an even greater influence on the contractor's management and its ability to accomplish contract specifications and improvement goals in cost and delivery.

This influence is brought to bear through several means:

- The work of the Navy program manager and field supervisor
  - quality of decisions
  - speed, timeliness, delays in making decisions
  - ability to interpret contracts and specifications and make on-the-spot decisions without lengthy recourse to higher authority
  - imagination, feasibility
  - awareness of the impact of decisions on the contractor's costs and delivery
- The willingness and ability of the Navy to focus on productivity improvement and to require its contractors to establish and achieve productivity goals and incentives for the mutual benefit of the contractor and the Navy

- The willingness and ability of Congress and the Navy to make economic lot size purchases
- The Navy's ability as an organization to work with ship designers and shipbuilders to design ships for ease of producibility
- The Navy's ability to staff procurement, liaison, and field offices so as to establish a long-term continuity of relationships and policies

The committee observes that the quality, delivery, and attitudes of program managers and field supervisors vary considerably, with significant impact on the contractor.

The "right" program manager, field supervisor, and staff make a substantial contribution to smooth and efficient production decision making. Many shipbuilders and suppliers feel that the lack of continuity in Navy management assignments adversely impacts productivity progress. This makes it difficult for the Navy to manage its business, and assist and cooperate with the contractor to accomplish savings in time and costs.

The climate for improving productivity is greatly influenced by the Navy. Many contractors feel that the Navy is interested in the objectives of product quality, contract conformance, and performance of the end product and its on-time delivery to a greater extent, than in the long-term goal of shipbuilder and supplier productivity improvement. The emphasis is on meeting the terms and conditions of the contract rather than on making improvements in cost and delivery during the life of the contract. In this sense, the climate for productivity improvement is far from ideal, particularly when the Navy manager's attention is on meeting existing regulations rather than on accommodating changes suggested by the contractors for saving time and cost.

There are several possible remedies for this situation in which contractors appear more interested in productivity improvements than the customer. One such remedy would involve writing language into the contract to encourage and facilitate productivity inducing changes (contracts with enhanced profit incentives contribute to this objective to a considerable extent). Another, not necessarily mutually exclusive, change would be to adjust the Navy program manager's and field supervisor's job content (including performance review) to place more emphasis on facilitating productivity improvements.

In summary, the reward system is probably a key to changing the climate for productivity improvement. All of these innovations would be enhanced by providing a focus within the Navy management structure for productivity improvement.

Managers and Management Development

As the performance of industrial operations depends so much on the competence and spirit of industrial managers, it is important to close this section with observations on this subject.

During the course of its work, the committee visited shipyards, met with many shipyard managers and management personnel, studied case histories of investment and innovations in the industry, and analyzed the financial and business performance of about 20 leading firms. From this exposure and data, the following conclusions stand out:

- A number of companies have performed far better than the average. There is an unusual spread in the range of performance of management.
- A few companies have clearly developed an outstanding group of managers from top to bottom.
- However, the performance of shipyard managers is adversely influenced by the following:
  - The cyclical nature of the industry and its slow, real rate of growth makes it a less attractive industry for managers.
  - Its technology is being specialized to the point that managerial skills are considered less transferable than in many industries. Hence, the industry is somewhat isolated and ingrown, and is slow to learn from other industries.
  - The technology of the industry has been relatively slow-moving, allowing managers to survive with only modest personal growth and change.
  - The poor performance of the industry as a whole discourages investment in human resources.

In contrast, it is clear that if naval shipbuilding is to become more productive, the demands upon industrial management will change considerably. More emphasis and skills will be required in computer-integrated information systems and advanced process technologies. Vastly more complex scheduling and communications can be anticipated.

The industry leaders have, generally, placed far more emphasis on developing excellence in management than the followers. The performance of a number of those firms is remarkable. They have grown, invested, increased market share, installed new technology and facilities, and pioneered in new shipbuilding standards and process. Their performance challenges the notion that naval shipbuilding is a losing business, a dying industry, and is managed by obsolete managers.

These companies have attracted and developed clearly outstanding, aggressive, disciplined, and innovative managers. Their salaries are competitive; they invest in management training and development; they have professionally organized performance evaluation and development systems; and they place attention on management as a critical resource for the company. Their focus on the quality of management stands out clearly in contrast to the rest of the industry.

It is apparent from the above evidence that development of outstanding management as a key resource should become a major thrust of the naval shipbuilding industry. Once recognized as being of basic

importance by top management, many ingredients of effective management development can be analyzed, evaluated, and corrected or improved as necessary.

Examples of the kinds of steps which over a period of time can help to develop an outstandingly capable management group are provided in Table 15. Management development is time-consuming and can be expensive. It takes patience and perseverance and "staying power," but it is perhaps the first and most important job that the Navy and each contractor's board of directors might insist be carried out if the U.S. naval shipbuilding industry is to become more productive, innovative, and healthy.

NAVY POLICIES AND PROGRAMS

In the virtual absence of significant merchant marine business, the Navy is the shipbuilding industry's only major customer. Thus, the Navy's interest and activities in productivity improvement have ramifications not only for the Navy but also for that portion of the U.S. defense mobilization base which is comprised of shipbuilders and their suppliers. Without normative national agreement on how large a shipbuilding, and supplier, industry the United States needs, and without other national programs to this end, the Navy has de facto stewardship of the industry, even though this is the responsibility of the Maritime Administration, under the Merchant Marine Act. Thus, the scope of this section includes the effect of Navy requirements, policies, and programs on the demand for ships and suppliers' products and the effect of acquisition policy on business conditions, as well as Navy programs aimed specifically at productivity improvement.

Addressing the Problem of Insufficient Demand

The U.S. Navy has depended on the U.S. commercial shipbuilding and supplier industry for the construction of all new Navy ships since 1968. At the same time, the U.S. shipbuilding industry depends on the Navy for about 80 percent of its business.

The naval ship construction market can be characterized as having four distinct segments, distinguished by the types of naval ships they construct. These segments are (see Tables 1 and 2):

- Nuclear-powered ships including ballistic missile and attack submarines, aircraft carriers, and nuclear-powered cruisers.
- Conventionally powered warships, consisting of guided-missile and gunned variations of cruisers, destroyers, and frigates.
- Noncombantant ships, including amphibious, auxiliary, and service vessels.
- Coastal ships and patrol craft.

TABLE 15 Key Ingredients in Successful Management Development

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Philosophy/Understanding

1. Its importance as the most important resource
2. Support and staying power for continuity from the top
3. A major rebuilding or renewal program takes 5-7 years
4. Unwillingess to compromise with less than the best

Tool/Techniques

1. Inventory/appraisal of all managers to identify
    - candidates for promotion
    - candidates for demotion
    - attitudes, skills, and understandings needed for personal development of each manager
    - programs/plans for each manager
2. Systems of coaching and career development for all managers
3. General management courses and training
4. Specific functional courses and training
5. Specific technique courses and training
6. Increased communications for managers - vertically and horizontally
    - company strategies
    - competitive problems
    - financial and nonfinancial performance results
7. Increased lateral assignments across departmental, divisional, and functional lines
8. Compensation - is it competitive
is it motivating
9. Recruiting for top talent
10. Tightened standards of performance/rigorous and disciplined, tough-minded action to replace poor performance.

Navy policy is to award ships from the first category to two shipyards. These two shipyards compete for attack submarine construction, but not for the other categories of ships in this segment. The funds for constructing these types of ships represent almost 40 percent of the Navy's new construction budget for fiscal years 1984 to 1988. These programs are stable in that the level of effort remains relatively unchanged through the entire budget cycle. Since only two shipyards are involved, a high degree of confidence can be placed in a future, large workload over a fairly prolonged period.

The second category is characterized by strong initial competition for relatively high-cost ships, where usually a large potential number of ships of a class are to be built. Here again, after winning the initial competition, the shipyards can see a relatively stable future workload over a fairly extended period. At this time, three companies (four shipyards) make up this segment and the funds for constructing these types of ships represent almost 35 percent of the Navy's new construction budget for fiscal years 1984 to 1988. These shipyards and those in the previously designated segment have shown a strong inclination to invest in technologically advanced capabilities to enhance their productivity in support of new construction and place themselves in the best-possible position to compete. The major difficulty for shipyards in this category is the ability to stay in it. Major Navy programs which support this segment do not always occur at times permitting continuity for any of the shipyards; there is vigorous competition each time a major program is initiated. Where healthy programs are curtailed or a shipyard loses a competition for ships, the shipyards in this category may drop to the third segment or revert to overhaul and repair.

The third segment is comprised of the remaining shipyards capable of constructing large naval noncombatant and commercial ships. At present eight shipyards in this segment are involved in naval construction, competing for about 27 percent of the Navy ship construction budget for fiscal years 1984 to 1988. The type of ships included are less complex than those in the prior two segments and less costly per ship. The numbers to be built of any one class are usually much smaller than the numbers in the second segment, and competition is so fierce that winning the first of a class does not assure subsequent follow ship awards. These ship types also are historically the first to be deterred, reduced in number, or cancelled in a typical Navy budget cycle. It is this segment of the industry where the Navy has allowed many shipyards to participate in Navy shipbuilding programs, to maintain the potential base for mobilization.

This segment provided much of the commercial ship construction when there were commercial ship construction programs. The demise of the commercial workload has resulted in a situation where there are insufficient naval shipbuilding opportunities in this category to support a technologically advanced industry comprised of the current number of shipyards. The result is that the current cost of building segment-three ships is significantly higher than it would be if the number of shipyards were less. The Navy's de facto policy to keep the maximum number open in this third segment results in a de facto subsidy

to maintain the larger number. Without sufficient assurance of future potential workload, these yards have not, and probably will not, make the necessary investment for enhanced productivity for new construction that has been the case in the first two segments.

The fourth segment is characterized by shipyards that have specialized niches in smaller-sized ship types. On a lesser scale than segments one and two, this segment is relatively secure, and their future, while very competitively achieved, seems assured.

In summary, Navy contract awards have kept the shipyards occupied, but for much of the shipbuilding and supplier industry, the workload has been far below an economic, productive level. The cost of this is buried in hidden subsidies to the segment-three shipyards. The only other alternative within the authority of the Navy would be to concentrate contracts in a smaller number of segment-three shipyards as they have done in segments one and two. The greater workload stability that would result would lead to productivity improvement, including reduced cost, as it has in the other sectors. The question of how to support the mobilization base would then become a separate issue.

It is not sufficient, however, from the standpoint of national policy to continue to ignore the progressive deterioration of the mobilization base. Some of the proposed solutions, reviewed in an earlier section, transcend Navy responsibility and require national, or congressional, resolution. From a technical standpoint, the province of the committee, those solutions which build on advanced technology to create a more competitive and financially attractive industrial environment are preferable to the subsidies of the past.

Productivity Improvement Programs

The Navy typically takes the attitude "I am the customer, productivity is the business of the supplier." Yet the Navy is the principal beneficiary of enhanced productivity. Furthermore, many productivity improvements have benefits which transcend the ship construction phase. Computer-aided design/computer-aided manufacturing (CAD/CAM), for example, not only enhances shipbuilding productivity, but also introduces efficiencies into ship design, ship operation, and ship maintenance, repair, and overhaul, all of which are direct Navy responsibilities. Thus, the Navy does not help itself by taking the attitude that productivity is a supplier problem. However, the Navy does not at present have any organizational structure specifically charged with shipbuilding technology or shipbuilding productivity improvement, even though the ship construction and overhaul budget amounts to a sixth of the entire Navy budget. In contrast, it is commonplace in much of industry for the customer to take a direct interest (and exercise an active hand) in the productivity of the supplier. Without a focus for productivity improvement, each shipbuilder and each NAVSEA acquisition manager is constrained to go it alone. The consequences of this, and the potential of providing a focus, are suggested by the following:

- All phases of Navy shipbuilding and life cycle support operations can be strongly affected in a positive way by a computer-integrated manufacturing philosophy which starts with a computer-based common engineering data base and extends to and supports all phases of the ship life cycle. Without focused Navy leadership in this total concept, the benefits from computerization will continue to be sporadic and minimal.
- The Navy sponsors production technology improvement through the DOD-wide Manufacturing Technology Program, and productivity enhancement through the test Industrial Modernization Incentives Program, and it also supports the joint Maritime Administration and Navy National Shipbuilding Research Program. However, the gains derived from these are limited by their timeliness, predictability, and level of funding, in proportion to the task, and to some extent by lengthy project selection and funding procedures. The provision of a single focus within NAVSEA for shipbuilding productivity could provide needed leadership in this area. It also could ensure that, in U.S. Department of Defense (DOD) programs, the Navy retains maximum flexibility in its approaches to productivity improvement with its contractors.
- The same focal point also could enhance productivity through better communication among all parties. The conduct of symposia and other communication enhancement efforts among shipbuilders amd suppliers could achieve material gain for minimal efforts. In addition, an industry advisory group could be created to provide this Navy entity with comments and advice to expand its activity and critique its progress.
- Despite their major contribution to shipbuilding programs, shipbuilding supplier companies are a low priority with regard to the Navy's interest in and receptivity toward new ideas and productivity improvement. There is little evidence of Navy-shipbuilder-supplier shared interest and involvement in the area of productivity enhancement, especially with regard to improvements that have a payback period that exceed that of on-line Navy programs. The Navy would be well served by providing a focus for reviewing, promoting, and diffusing product and productivity improvements that originate outside the Navy. From the standpoint of the shipbuilder and supplier, such a focus would serve the role of ombudsman or advocate for productivity improvements which exceed the scope of on-line programs, or, in some cases, the tenure and hence interest of other potential sponsors.

A productivity program would take the long-term view of the Navy's productivity interests. An even more comprehensive step would be to establish a productivity improvement chain of command within the Navy to serve a function analogous to that of the R&D chain of command, that is, to monitor, oversee, plan, and direct private and public sector productivity improvement efforts in support of overall Navy missions. This would build into Navy personnel practices the opportunity for professional recognition for achievements in productivity improvement.

The productivity improvement chain of command would: administer DOD and Navy productivity improvement programs; work with other Navy offices to structure acquisition programs to promote productivity improvement; assist Navy contractors in obtaining Navy support, concurrence, or participation in contractor-initiated productivity improvements; and stimulate, coordinate, and undertake productivity improvement projects as called upon and as appropriate. Candidate areas include standardization, electronic data transfer, and computerization. As such an initiative matured, the Navy could consider earmarking a percentage of acquisition program dollars for productivity improvement programs, in a manner analogous to that employed in R&D.

Effects of Navy Contracts on Productivity

Shipbuilding productivity improvements have been most significant since 1976, when the Navy implemented a ship acquisition strategy of providing increased financial risk and also profit incentive to the shipbuilder, increased competion, a greater number of multi-ship contract awards, and improved government/contractor working relationships.

The Navy has improved contract terms to protect the government's interests properly but also recognize the shipbuilder's particular problems. However, there is opportunity for further improvement. Contracts that allow economic lot-size production runs enable shipyards and suppliers to accumulate capital, modernize facilities, and improve efficiency. When combined with incentive provisions that enable the shipbuilder to make a profit, such contracts encourage management to implement the most efficient production techniques.

The continuity and stability of such procurements reduce costs to the Navy, improve delivery time and ship quality, and promote standardization. However, this rarely seems to be an important consideration in the awarding of Navy contracts, especially for auxiliary vessels. For example, the Navy does not contract for a batch of similar, though not identical auxiliaries, however, batch-ordering of combat systems destined for different ships is commonplace.

The Navy still does not seem to appreciate fully the seriousness to the shipbuilder of timely payment and minimal retention. With interest being a nonreimbursable cost, the inability to use cash truly earned is a serious financial penalty. Retentions, in particular, are a significant source of funds for capital improvement; the Navy could do more to manage and release them to this end. In addition, the Navy could assist its shipbuilders by being a vocal proponent within government for the retention of important tax provisions such as depreciation of tangible assets (CAS 409) and cost of facilities capital (CAS 414). These provisions have been vital to achieving productivity enhancement features in shipyards which have benefited the Navy directly. In addition, greater use of the Navy's authority to provide compensation in the event of program cancellation would encourage capital improvements.

It would also be in the Navy"s interest to take the lead in seeking a tax deferment for shipyards on profits that are reinvested in capital improvements which benefit the Navy. This is a concept similar to the Capital Construction Fund Program available to U.S. commercial ship operators, which provides funds for replacement and improvement of facilities.

Productivity Improvement in Overhauls

While the committee's assessment was directed to new construction, it was interested in the extent to which the opportunities for productivity improvement that it identified address the future Navy workload, which may emphasize conversion, modernization, and overhaul over new construction.

Nature of the Workload

Once the Navy reaches its intended goal of 600 ships by the early 1990s, the Navy ship construction budget will be increasingly directed to conversion and modernization because the 600-ship fleet will not be completely modern unless the policy on the size of the Navy is changed. By the mid 1990s, for example, the first of the FFG-7 class will be almost 20 years old. Despite the emphasis on overhaul and modernization, there will be some new construction opportunities. The DDG 51 Program will extend well beyond 1990 until perhaps the year 2000, and CG 47 Class procurement is planned through fiscal year 1989. Navy planning calls for additional aircraft carrier procurement in the early 1990s. There is also planning relative to a new class of frigates to be built toward the end of the century.

Applicability of Productivity Improvements to Overhaul and Modernization

The keys to successful performance of complex overhauls or modernizations rest upon: early identification of the work to be performed; early development of the alteration work packages; use of long lead-time procurement for hard-to-obtain items; early material ordering, with material arrival dates in-yard sequenced to support the planned overhaul work package schedules; and ability to react quickly and effectively to the inevitable emergence of unplanned work.

Those productivity improvements assessed by the committee that support the above contribute to a more productive effort. Development of a common engineering data base will enhance the ability to maintain accurate control of a ship's design through the construction and operational periods. The management methods being instituted are fully applicable to ship repair overhaul and conversion. The "interim product" logic of zone-oriented construction is almost equally applicable to overhaul and conversion work.

The availability of reliable design and planning data well in advance of the assigned industrial period will enhance the ability to reduce costs and schedules for the production work. The flexible manufacturing resources being planned and installed are almost totally adaptable to ship repair work and will lower overhaul costs and schedules accordingly. Still other applicable innovations include effective management systems for material identification, ordering and disbursement to the trades, early supplier involvement, and central procurement, especially where a number of the same types of overhauls are to be performed.

8

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APPENDIX A

MEMBERSHIP AND FINDINGS OF THE WORK GROUPS

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Findings

The national strategy for the shipbuilding industry has been to preserve a defense base by attempting to generate sufficient sales income to maintain the status quo in the industry by having the taxpayer subsidize both the shipbuilding and ship transport industries. At present, however, there are insufficient sales dollars available to sustain the U.S. shipbuilding industry as it is organized.

- There is sufficient demand to support substantial investments in the two private, nuclear-qualified shipyards.
- In the future, a political decision will have to be made concerning the number of non-nuclear combatant shipyards. If left to economic considerations alone, and without development of potential overseas markets, there will be a contraction in this segment of the U.S. shipbuilding industry sometime in the next few years.
- Those shipbuilders in the amphibious, auxiliary, and service ship business face a questionable future. Short of positive national steps, there will be a contraction in this segment of the industry, and until the shake-out takes place, there will be little hope of investment in the segment.
- The fourth tier of shipbuilders, the boatyards, is characterized by companies that have found specialized niches. Their future is somewhat more secure.

Profit accumulation is the key element in the capital formation process. Capital formation is the most important element in the efficiency and modernization of the industrial base. More profit may mean lower cost in the long run.

Most successful companies have anticipated the need for investment and have made large at-risk commitments in a timely manner.

Multi-year, multi-ship ship contracts have allowed shipyards to accumulate capital, modernize facilities, and improve efficiency. This form of contract when combined with incentive provisions that enable the shipbuilder to make a profit has encouraged management to implement the most efficient manufacturing techniques. The continuity and stability of such procurements reduce costs to the Navy, improve delivery times and ship quality, and promote standardization.

Within national security constraints, an expansion of foreign military vessel sales would increase the sales base.

U.S. shipbuilers and shipbuilding suppliers are an element of the U.S. defense mobilization base. Moreover, in the absence of significant merchant marine business, the Navy is the industry's only major customer. There is now no normative agreement on how large a shipbuilding industry the United States needs. The Navy has assumed de facto stewardship of the industry, including the mobilization base, even though this responsibility is assigned by the Merchant Marine Act to the Maritime Administration. The Navy's needs do not necessarily relate to economic or industrial stability; rather, they are keyed to naval force doctrine and strategy. This fundamental conflict pertaining to the stewardship of the shipbuilding industry should be examined to correct this anomaly in national policy.

The progressive reduction in number, and increased specialization of the active shipbuilders and suppliers is sensible in terms of industry efficiency and cost to the public for naval ships, but the direction is counter to assumed mobilization requirements. If the U.S. cannot sustain the shipbuilding base required for national security needs through free market approaches, then a government supported program will be necessary. A program for the national security would be based on considerations other than economic efficiency, such as geographic dispersion.

One must recognize that foreign sources of capital can be employed when domestic sources are neither available nor at equally attractive terms. While national security considerations provide inhibitations to foreign investmments, equity positions could be easily taken, it appears, especially in the class of shipyard that builds auxiliary vessels. The impetus for the use of these foreign funds, national interests notwithstanding, may be the natural outcome of the U.S. capital market's reluctance to provide long-term debt capital, and equity capital, to all but a limited number of defense contractors.

Issues associated with capital formation are common to all firms within the shipbuilding industry, that is, market position determines a firm's profitability and subsequent retained earnings base, as well as the ability to use external sources of financing. What differs, however, are the firms' strategic planning and investment decision processes and the timely implementation of programs.

These market opportunities are exclusive U.S. Navy demand, which implies that the investment decision making of the yard is dependent on the procurement process. In fact, capital formation is a misnomer. From an economic standpoint, the issue is imperfect demand-- insufficient sales dollars industrywide to sustain the number of shipbuilders and suppliers. The procurement contract, once obtained, is a bankable commodity. However, the long-lead times associated with program development results in extremely high and (from the Navy's standpoint) non-expensible interest costs. While these expenses flow through to the income statement, interest expense hits profitability very hard. It may be the case that third-party financing (e.g., tax partnerships, lease transactions) may not only improve the shipyards' profitability but allow them access to capital at a lower cost.

Government regulations and Navy procurement policies and practices have a substantial impact on investments made by the industry. Particularly important are the following:

- <u>Progress payments</u> reduce working capital requirements, thereby lowering ship costs and also releasing corporate capital for investment in fixed assets and/or research and development (R&D) to improve the product and/or manufacturing productivity.
- <u>Indemnification of investment in facilities</u> reduces uncertainty concerning actions beyond the contractor's control, such as program cancellation. The Navy should use this authority more broadly and frequently to encourage capital improvements which will result in lower costs to the Navy. It also puts to rest doubts in the financial community concerning the continuity of government programs.

- Cost of facilities capital (CAS 414) has positively affected shipbuilding capital investment. The program should be retained, and changed to make the allowable cost equal to the long-term cost of money.
- Tax deferred profits. The government should allow shipbuilders to defer taxes on profits if the profits are reinvested in capital improvements which will benefit the Navy.
- Depreciation of tangible assets (CAS 409). The same accelerated depreciation as used for tax purposes also should be permitted to be used on defense contracts.

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Findings

State of Practice

Technological advances over the last several years have resulted in the development and application of extremely effective production management systems. These trends show promise of completely transforming the technology of manufacturing. Through the application of these advances, traditional manufacturing industries are reporting improvements in terms of lower cost, production schedule improvements, and greater quality control. Of particular interest to this study is the way the application of computer and information technologies to manufacturing is leading to productivity improvement in all types of production. Experience to date suggests that modernization of production management systems by shipbuilders and their suppliers also is likely to result in substantial productivity improvement. The primary issues in modernization, however, are not the technical capabilities. These capabilities have and are being applied with high levels of demonstrated success. The real issues involve the commitment to the organizational, procedural, and human considerations required to implement available technology, and to advance the state of the art of the naval shipbuilding industry.

While most naval shipbuilders are undertaking developments of various production management systems, many of these systems are not advanced from the standpoint of integration and use of advanced tools such as state of-the-art data base management systems. The experience of other industries indicates that there are significant advantages to be gained from the use of integrated systems which make use of these tools.

It appears that shipbuilders are just now feeling some of the pain of computerization that the aerospace industry suffered about 10 years ago. Naval shipbuilders have concluded that there are significant advantages to be gained from computerization. They have taken action in the last 2 or 3 years in the right direction. However, the shipbuilding industry has an advantage today--they can take advantage of lessons learned in other industries, such as aerospace, in which production management is more completely integrated and computerized.

Importance of Planning for Systems Modernization

Development of a plan for systems modernization is an essential first step in moving to a more productive manufacturing environment. Inadequate planning prior to launching production management systems programs is a major reason why many companies' results fall short of their expectations when investing in new systems.

While most shipbuilders have systems development plans, the scope of these plans is often too narrow to provide true horizontal integration across functional boundaries. The result is frequently extensive delay and distortion of information at the many functional interfaces throughout the shipbuilders' supply chain. Systems planning must therefore place integration on a par with the functional objectives to be attained.

Shipbuilders will also need to expand the time horizons of their systems plans to reflect the long-term nature of production management systems modernization. Five years appears to be a minimum planning horizon for developing and implementing significant changes in manufacturing systems.

Production management systems cannot be developed in a vacuum. Concurrent with the design of supporting information systems, efforts need to be directed at ship design, ship production planning, and production methods and processes, because all are interdependent and interactive. Information system development should be undertaken in parallel with these other developments to the extent that requirements for information systems can be defined.

Relation of Production Management Systems with Other Areas for Productivity Improvement

Productivity improvements are achieved through the following mechanisms, all of which must be supported by top management: organizational change, improved human relations and indoctrination and training, process or method changes, and implementation of automated and integrated systems. Changes in any of these areas affect the other areas. It is impractical to distinguish between the relative productivity improvements due to process changes versus computer system implementation if the objective is only to pursue a single course of action. Production processes and production management systems are best improved by performing structured systems analysis to identify cost drivers, process changes, and information needs. Horizontal integration of information is most efficiently achieved through systems analysis and is necessary even if computerization does not result. Systems analysis must be performed on a broad company basis so that islands of automation or process change do not later become barriers to innovation at a later date.

Navy Role in Systems Modernization and Productivity Improvement

The Navy is responsible for the implementation of production technology advancement programs such as the Manufacturing Technology (MT) Program and also productivity enhancement programs such as the test Industrial Modernization Incentives Program (IMIP), which are authorized for execution on a DOD-wide basis. Each military service is implementing these programs with varying degrees of emphasis and success, depending on the degree of support provided by top-level management. The attitudes of lower-echelon acquisition managers toward partnerships with contractors to achieve mutual benefits through productivity ehancement is also important. Relative to other military services, the Navy exhibits a fragmented approach with contractors in seeking productivity enhancement. This includes production management system development and implementation, to provide vital communication linkages within each shipyard, between lead and follow yards and their suppliers, and with Navy and its design agents. The Navy is now in an excellent position

to capitalize on the production management system technology advances already working effectively in other industries, thereby minimizing cost and risk. The implementation of common data bases is considered to be a logical starting point.

Shipbuilding productivity improvements have been most significant since about 1976, when the Navy implemented a ship acquisition strategy of providing enhanced profit incentive to the shipbuilder. However, this approach needs to be complemented by joint and dedicated involvement by a centralized Navy source with shipbuilder and supplier industry personnel responsible for productivity. The Navy sources must be fully supported by a dedicated long-term commitment by top-level management. It is evident that in most Navy and contractor organizational and contractual relationships, a balanced interface situation is achieved in such areas as ship system engineering, accounting, and contracting. It is not evident that there is an equivalent organizational entity within the Navy which provides a dedicated involvement with the shipbuilders and their suppliers on productivity enhancement matters.

Applicability of Air Force Programs to Shipbuilding Productivity Improvement

The composite architecture of manufacturing developed by the Air Force's Integrated Computer-Aided Manufacturing (ICAM) program is not useful for designing shipbuilding production management systems. However, the methodology of functional modeling developed and used in the ICAM program can provide the shipbuilder with a means of formally defining production system models as an aid in developing these systems. The ICAM program also provides a model of industry and government collaboration for a common objective, which could benefit the Navy, the shipbuilder, and the suppliers, if pursued. An example of a useful product of such collaboration could be the development of a manufacturing cost design guide tailored to ship design and production methods, such as has been prepared under the ICAM progam for airframe construction.

Importance of Electronic Data/Bases/Computerization

The Navy expects to convert its enormous volume of design, construction, and fleet support data and documentation to electronic form at an increasing pace. As stated, the Navy ship-related commands, as well as the marine design agent and shipbuilders, are now using computer applications to increase productivity in design, construction, and fleet support. These applications are independently developed, and while having many similarities in approach and data employed, they will not exchange information directly.

The supply chain for naval ships, over its life cycle, is characterized by constant handoffs of significant development actions and supporting data from Navy agencies to private sector firms and back to Navy agencies.

The benefits of computer-assisted design and production management systems to reduce schedule periods and manpower for required tasks and to provide improved results will be lost if the supply chain is unable to transfer the needed data effectively.

A NAVSEA and industry (i.e., shipbuilder and supplier) cooperative planning mechanism is needed to provide a basis for understanding and communication among the parties involved in the supply chain. Development of an industry-level architecture describing the required data, applications, and controls is now necessary. A Navy point of contact is needed to prepare and execute the plan for industry involvement. Effective data transfer will be a significant challenge to achieve and will require, as it did in the airframe industry, dedication by both the Navy and industry. Delay in this integration planning will frustrate both Navy and industry efforts to utilize computerization fully in the ship supply chain.

Changes Needed in Cost Reporting Systems

The requirements concerning ship work break down structure (SWBS) and cost and schedule reporting are not compatible with the implementation of zone-oriented ship design and construction methods. These technologies will require production management systems to be re-directed from a trade-class or system orientation to one of multi-trade/multi-system/area management. Cost and progress reporting in accordance with the NAVSEA requirements therefore becomes burdensome and the data accuracy will by necessity be questionable.

NAVSEA enginering functions have a technical need for documentation in accordance with the existing SWBS, i.e., weight control programs and initial system definition. There is, however, no apparent need for utilizing this same SWBS-system for cost and progress reporting. A methodology or system for cost and schedule reporting is needed which fully recognizes the new and improved production technologies. The current SWBS should be used strictly for Navy design and engineering (as opposed to shipbuilder engineering and production) -related applications.

<u>Training to Support Computerization</u> Computers are increasingly being used to perform the paper work of manufacturering tasks as well as process control. Finding or training personnel to meet the skills needed in development, implementation, and operation of new systems is a problem. There is a drastic shortage of computer literacy and fluency in the United States. It was found that the wrong sytems were used on occasion and that multiple nonintegrated sytems were cumbersome and ineffective.

To cope with the lack of personnel, the shipbuilding industry must acquire experience from industries already employing computerized production management systems. Company training programs are also necessary, with the objective of providing design, planning, and operations managers with sufficient skills in system analysis to plan and manage computerization projects themselves, employing professionals

as project consultants. In this way, computerization efforts will be integrated with other business planning and will be compatible with or take advantage of existing equipment and systems.

The U.S. Navy needs to encourage the establishment of production management systems and the training of personnel with the objective of encouraging integration of systems.

Importance of Top Management Commitment Key to the successful development of more efficient construction and management methods is management commitment to modernizing shipbuilding technology. Methods must be developed to convey information on the advantages of systems modernization to all levels of management to ensure their interest and direct involvement. Management needs to plan the methods of operation 5 to 10 years into the future. Management must be willing to assign, develop, or procure the necessary skills for the proper analysis of present and future operating methods and the necessary systems development effort. Management must be trained to operate with the greater visibility afforded all levels of management by computerized management systems. Management incentives need to be structured to reward long-range planning and systems modernization as well as short term job performance.

Relation Between the Application of Group Technology and the Modernization of Production Management Systems Traditional manufacturing applications of group technology have limited application to shipbuilding. However, the concept of group technology can be productivity applied to both ship design and shipbuilding, as developed and described in several National Shipbuilding Research Program reports. To attain more benefit from the application of these concepts:

- Additional training and education should be performed of managers, designers, planners, and production supervisors in these concepts and their shipbuilding applications.
- Additional refinements of the concepts tailored to ship design and production products and processes should be developed with the intent of integrating these within computerized production management systems.
- Shipyard management must realize that to achieve the productivity advantages of group technology-organized production, more design and work planning effort is required than has been traditionally been needed.

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Findings

Zone-oriented ship construction techniques are used for constructing naval ships, including combatants of all sizes and types. These techniques have the potential of creating substantial cost savings and schedule improvements, with concurrent improvements in quality and safety. These approaches are successfully being applied in facilities and ship designs. Benefits accrue even on single ship efforts. Maximum benefits are obtained when the methods start to be applied starting early in the contract design phase. Additionally, when production documentation is properly organized, this approach will support subsequent conversion and repair. Zone-oriented design and construction is finding selective application in U.S. naval overhaul and conversions.

The transformation of U.S. shipbuilding practices to a zone orientation is clearly in the Navy's interest. Yet, the improvements that have been made to date have been made on an ad hoc basis, based on each shipyard's pursuit of its own objectives, obtaining Navy concurrence and support on a problem or project-specific basis. The Navy does not at present have any organizational structure specifically charged with shipbuilding technology or shipbuilding productivity improvement. To support and take full advantage of shipbuilders' applications of zone-oriented ship design and construction effectively, the Navy needs to take account of the following:

(1) Zone-oriented shipbuilding methods require much more extensive production planning and much closer integration of design engineering with production planning than is the case with system-oriented techniques. This added planning effort and the resulting reduction in production effort and schedule creates a very different schedule structure and results in overall cost and schedule reductions.

(2) Zone-oriented shipbuilding methods require changes in the ship acquisition process, including procurement and delivery schedules, and use of techniques for advancing delivery of government-furnished information (GFI) such as ship system engineering standards.

(3) Zone-oriented methods require more extensive and more carefully planned lead-yard support for follow yards. The relationship between the Navy, the lead shipbuilder, and the follow shipbuilder requires early and precise definition prior to the commencement of lead -hip detail design.

(4) Zone-oriented shipbuilding methods require a change in basic logic employed for shipbuilding. The ease with which transitions will occur for both the Navy and the shipbuilder is directly related to the pertinent knowledge participants possess. People need knowledge of pending developments to relieve their apprehensions and to contribute intelligently. The most effective way to provide such knowledge is through formal education of senior management, middle management, college students, and first-line supervisors and the work force. Specific programs are needed for the Navy and for shipbuilders. The range of educational

developments needed includes seminars, continuing-education courses to be included in industrial engineering curriculums, and worker training sessions.

(5) It is essential that a carefully thought out building strategy be developed by the shipbuilder's production engineers. This strategy then controls the design engineering effort in terms of sequence of work, schedule, and format and content of documentation. The building strategy also drives the schedule of required vendor-furnished information (VFI), government-furnished information (GFI), contracter-furnished material (CFM), and government-furnished material (GFM), and hence is of direct interest to the Navy.

(6) Full use of zone-oriented ship design and construction methods requires different design documentation than has traditionally been supplied. Typically, this involves diagrammatic presentation at the system level, and detailed physical information at the zone level, with a ready means of correlating the two. Navy acceptance of the differences is starting to develop in several ongoing programs, and should be continued.

(7) The use of zone-oriented construction methods will necessitate development of close working relationships between the shipbuilders and the suppliers of all equipment, including GFE. Suppliers under contract to the shipbuilder must recognize that the shipbuilder needs engineering data in greater detail and sooner than before. Furthermore, the shipbuilder will be less tolerant of delays or deviations from the production schedule because the window for installation of the supplier's equipment will be smaller and the consequences of any rework necessitated by the supplier's slippage will be greater. The chain of contractual relationships which link the shipbuilder to the ship acquisition program manager (SHAPM), the SHAPM to the participating acquisition requirements manager (PARM), and the PARM to the equipment vendor can be a deterrent to quick response to emergent information requirements and rescheduling opportunities. Methods to facilitate controlled information flow between the shipbuilder and the GFE supplier are essential to assure that maximum gains in productivity can be achieved. Meetings of all parties involved, contract clauses which encourage direct supplier-shipbuilder dialogue, and other methods have been used on various programs. Methods chosen should be suitable for general application to all ship acquisition programs.

(8) Other changes in the contracting process, such as minimizing the number of contract drawings, essentially drawings that can be modified by the contractor only with prior government approval, can reduce shipbuilding costs, including the cost of necessary and desirable changes.

Accuracy Control and Statistical Documentation[1]

Adoption of zone-oriented shipbuilding methods creates opportunity for applying statistical control of manufacturing operations as a means of achieving constant improvements in productivity. One impediment is there is not yet sufficient understanding within the shipbuilding industry and the Navy. Two shipbuilders have started collecting prerequisite data for hull construction of warships, including aircraft carriers, surface combatants, and submarines.

Statistical analysis of accuracy variations of a shipyard's work processes can be used to predict how accurate hull structure will be in a ship never built before. Abilities to withstand high-impact shock are directly related to accuracies achieved without forced fitting during construction processes.

As productivity depends in part on quality and since accuracy control provides an analytical basis for less direct inspection, the prospects for savings in the aggregate, by both shipbuilders and the Navy, are enormous. The Navy needs to encourage all shipbuilders to develop statistical control of manufacturing.

Maximum submergence depth of a submarine is related to the degree of hull circularity achieved and absence of locked-in stresses. Thus, the Navy's possession of statistical evidence of accuracy (i.e., quality) from particular shipyards before award of contracts would serve military requirements.

[1]Additional viewpoint submitted by Lou Chirillo.

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Findings

From the standpoint of the suppliers of services, equipment, and material (i.e., about 5,000 companies), the naval shipbuilding market is characterized by inadequate profit and growth potential, insufficient production volume, and undependable forecasts of future volume. Attempts to distribute available work to many suppliers and to level-load suppliers over time adversely affect the potential of suppliers to develop economic-lot-size production runs. These long-term conditions have been a considerable disincentive to suppliers who might otherwise participate in naval shipbuilding programs. Uncertain product demand has resulted in naval shipbuilding suppliers retarding plant modernization and productivity improvement. Retention and attraction of skilled labor also has been affected. As an initial step toward countering these long-term conditions that beset the industry, the Navy needs to develop a policy on the size of the shipbuilding industrial base--shipbuilders and suppliers--necessary for long-term naval support.

From the standpoint of national readiness for mobilization, there are major inadequacies in the shipbuilding supplier industrial base, which include inadequate facilities, surge capacity, access to materials, and time-responsiveness. Steps need to be taken to safeguard and strengthen the supplier base for the purpose of industrial preparedness for mobilization. In some instances, protections, subsidies and other noncompetitive practices are warranted, even though they sometimes have a dampening effect on productivity.

Although the Navy's ship acquisition program is less adversarial than in the past, suppliers and shipbuilders still consider the program to be unresponsive to their concerns. The Navy needs to develop a more cooperative working relationship with its suppliers, especially concerning the introduction of technology advances and productivity improvements, the development and updating of specifications, and efforts to standardize. For their part, suppliers need to have a voice in the government initiatives that affect them.

The disparate requirements of different Navy activities increase costs and introduce confusion, which makes the naval shipbuilding market less attractive to suppliers.

The Navy should adopt a policy that permits competition of flexibility among shipbuilders and suppliers while still maintaining standardization of form, fit, and function. Competition in the initial buy of an item can reduce cost, but subsequent buys should be sole source over a specified number of units (or options) to promote standardization. To the extent feasible, Navy purchases of original parts should include foreseeable overhaul and maintenance requirements to enable economic-lot-size production runs.

Over the life of mature shipbuilding programs, perhaps once a decade, the Navy should update the prevailing class design and seek to obtain from suppliers and shipbuilders ideas for new technologies and productivity improvements that result in lower cost within the overall context of the design and also standardization.

Often in Navy acquisition "standardization" is synonmous with identical. This inhibits the introduction and application of new

technologies and productivity improvements. Navy policies need to be changed or interpreted explicitly to allow the introduction and use of new technologies and processes that result in productivity improvements and lower cost while not affecting form, fit, or function.

The necessity of coping with substantial manufacturing lead times and small volumes of purchases forces the shipbuilder to consider innovative approaches to material procurement. Long lead-time procurements should be used more extensively to support master construction schedules. Option procurements can reduce costs and delivery times. Significant economies can be realized by purchasing onboard repair parts, specifically those with long shelf life, and which are not readily available, at the time that the original equipment is purchased. Considerable savings can be obtained by centralizing the procurement function for multi-ship construction or conversion programs in which several shipyards are participating on similar production schedules.

Communication between the Navy and its suppliers is inadequate on the status of current specifications, standards, requirements, interpretations and changes, and the need for changes. The citing of different editions of the same specification in different shipbuilding contracts (of the same shipbuilding program) is a particular problem. A system needs to be developed to simplify and speed the communication and implementation of changes, and the authority to use them. The system should also be capable of accommodating the shipbuilder's or supplier's occasional desire or necessity to use a different version of specification than the one cited in the contract without extensive administrative procedures, such as are involved in change proposals. It is appropriate to assemble a joint government and industry task force to devise the needed management system.

The suppliers' rights in data must be respected. The interpretation and application of the existing rules are having a detrimental effect on suppliers' technology development efforts. The rules are capable of very loose interpretation, which subverts the protection that is their intent.

In fixed price situations characteristic of procurements from shipbuilding suppliers, there is no incentive for the supplier to improve his product by means of the value analysis machinery, which is cumbersome, because he is required to share the benefit of the improvement with the Navy. Since the supplier is operating on a fixed-price basis, it makes more sense for him to internalize the innovation because the more the supplier can control costs, the greater will be his profit.

Clarification is needed by the Navy of the extent of responsibility of the shipbuilder for life-cycle system management.

Navy policy is for the contractor (i.e., supplier) to fund improvements in his product and productivity out of cash flow, ideally profit. The Navy also has a number of programs or procedures to promote innovation, such as the Manufacturing Technology Program, the Industrial Modernization Improvement Program, Value Engineering, and contractor-initiated engineering change proposals. These latter avenues for innovation are cumbersome and ineffectual. The policy to stimulate innovation by making Navy work more profitable for the

shipbuilder and, in turn, the supplier, is both laudable and successful, at least for shipbuilders and suppliers who perceive that they have significant potential for future Navy business. Nevertheless, the Navy lacks an organizational focus for reviewing, promoting, and diffusing product and productivity improvements that originate outside the Navy.

APPENDIX B

A CASE STUDY OF QUIET BALL-BEARING MANUFACTURE

Quiet ball bearings (hearinafter "NT-3 bearings") are used by the U.S. Navy on low vibration machinery on submarines and on an increasing number of surface ships to assure acceptably low structureborne and airborne noise levels. To qualify for acceptance, NT-3 bearings must meet the requirements set forth in military specification MIL-B-17931, originally issued in 1954. This specification was amended or revised eight times through 1975, when the current specification MIL-B-17931D was issued.

Until recently, suppliers of NT-3 ball bearings included the following:

- Barden Corporation,
- Hoover Bearing Company,
- MRC Bearing Company (Marlin Rockwell Co.),
- New Departure-Hyatt, and
- NTN Bearing Corporation of America.

All but NTN were domestic manufacturers at the time of their participation.

At present the Navy obtains its entire supply of NT-3 bearings from the foreign manufacturer, NTN Bearing Corporation of America, Totowa, N.J., which manufactures NT-3 bearings in Japan.

U.S. manufacturers have given up the Navy's quiet bearing business over a 15-year period. Since the reasons for withdrawal of the U.S. manufacturers remain and since this instance of the Navy's exclusive reliance on a foreign source for critical parts may not be unique, the events leading to the dependence on a foreign supplier are reviewed as a case study. It may be possible to gain some insight into the effect of Navy actions on U.S. manufacturers' productivity and to draw general conclusions concerning needed improvements.

HISTORY

Bearing Requirements

Quiet ball bearings are used in low vibration machinery of Naval ships to minimize structureborne noise, reduce airborne noise, and improve

operating performance. The original Specification MIL-B-17931 was amended or revised to reduce noise limits and to expand the specifications to larger-size bearings. The NT-3 requirements established in 1962 expanded the specifications to cover material properties, metrology, radial clearance levels, preload/axial end play values, and reduced noise limits. The latest specification covers more classes of bearings, increases noise test loads, and has noise limits for a low frequency band (50 to 300 Hz), medium frequency band (300 to 1,800 Hz), and a high-frequency band (1,800 to 10,000 Hz). Grease applications must meet a specific requirement.

Thus, manufacturers have faced ever more stringent noise require ments since 1962. As a result, a substantial number of difficult quality performance steps have become necessary to assure acceptance of NT-3 bearings under the demanding dimensional and vibrational requirements of MIL-B-17931.[1] For example, to ensure that the bearings meet the dimensional requirements, the manufacturer must place tight controls on every bearing dimension, under the premise that the tighter the dimensional control, the quieter the bearing. In addition, complex vibration tests, which provide a measure of the amount of deviation from circularity which exists on the balls and raceways of the bearings, are necessary to check the overall noise quality of the finished product.

Withdrawal of U.S. Manufacturers

In 1967, U.S. domestic manufacturers supplied approximately 85 percent of the market in NT-3 bearings. Their share fell to less than 4 percent by 1977. At present, the Navy is 100 percent dependent on one foreign vendor.

This withdrawal was first reported in 1978 when it was noted that the number of quiet bearings purchased by the Navy from domestic manufacturers was dwindling. The Navy recommended action to determine the cause. It was found that while the number of domestic bearings decreased, the number of foreign bearings provided by NTN Bearing Corporation increased so that an adequate supply of high-quality bearings remained available. Domestic manufacturers did continue to submit bearings for acceptance tests, but their bearings were rejected in increasing numbers. It has been reported that the overall quality of the typical domestic bearings has not been as good as that of the typical NTN bearing provided for acceptance tests. The domestic manufacturers contended that the profit margin for their bearings was. For example, to ensure that the bearings meet the dimensional requirements, the manufacturer must place tight controls on every bearing insufficient for them to compete under the MIL-B-17931 Specification with the

[1]The dimensional tolerances of the NT-3 bearings differ from the standards and tolerances established by domestic manufacturers for commercial bearings. There are five grades of precision for commercial bearings, in ascending order of precision: ABEC 1, ABEC 3, ABEC 5, ABEC 7, and ABEC 9. The NT-3 bearing is a mixture of these.

NTN Corporation. As a result, the domestic manufacturers slowed or ceased the manufacture of these bearings. Indeed the domestic manufacturers have generally declined to bid, or bid high prices, in response to Navy purchase requests for noise-tested bearings.

The NTN Bearing Company is an organization of substantial technical capability and financial strength. Sales of the NTN Bearing Company in 1982 were $821 million with a net profit of $32 million; and 1983 sales were $800 million with a profit of $26 million. The NTN Bearing Company has manufacturing facilities for ball bearings in three countries outside Japan. There exists an American subsidiary manufacturing some bearings in the United States as well as manufacturing facilities in West Germany and Canada. Bearings are close to 70 percent of all sales of this company, the rest being automotive parts and similar components. About 24 percent of their products are exported.

In 1979 a joint U.S. Department of Defense and industry meeting was conducted to address manufacturing technology. The Navy's quiet ball-bearing problem was discussed and industry's assistance in resolving the problems was sought. At that meeting, the Naval Sea Systems Command (NAVSEA) noted the lack of domestic suppliers for the bearings and asked any manufacturer interested in making the bearings or interested in developing a manufacturing technology program to contact NAVSEA. Only two manufacturers responded to the request and only one of the two has indicated an interest in discussing the details of manufacturing the bearings.

Reason for Loss of Interest

The dramatic decrease in interest by U.S. bearing manufacturers is the result of NTN's ability to sell their bearings at lower prices. In explanation of this advantage, some domestic suppliers complain that their machinery is old and incapable of producing the quality bearings required by the ever more stringent Navy specifications. The Japanese machinery is as much as 20 years newer than that of U.S. companies and the rejection rate of their bearings is much lower than that of U.S. vendors. Domestic bearings are primarily rejected due to excessive vibration levels. Once the bearings are rejected, the vendor is left with many specially made bearings for which there is no market. Despite this higher rejection rate, U.S. quality control and performance checks for NT-3 bearings are greater throughout the entire production process than for most commercial grade bearings, thus adding to the time and cost involved in producing them. In addition, the quantity of bearings usually involved in any lot purchase is small.[2] Because of the small volume of business, domestic

[2]There are 151 different quiet bearings and 24 different diameters. The total quantity is on the order of 15,000 to 20,000 purchased per year. This includes 90 percent deep groove, 10 percent angular contact bearings. The quantity procured per contract is increasing but still small. Navy expenditures per year, based on NTN prices, is about $1 million.

manufacturers could not justify the considerable investment necessary in dedicated production machinery, inspection equipment, clean room standards, and highly skilled labor.

Information available to the Navy indicates that the quiet bearings made by the Japanese are the result of strict quality control during the manufacturing process with extreme care applied to precision machining practices. It is further believed that the Japanese have developed and built special machine tools to finish the active surfaces, but, advanced manufacturing techniques and operations are not used. It is unrealistic to suppose that a lack of technical capability is the factor restricting domestic production.

By 1981, NTN Bearing Corporation had become a sole source supplier. NTN notified the U.S. Navy that, as a result of new internal company management policies, NTN was changing its NT-3 bearing program. NTN would no longer pre-plan for production of NT-3 bearings. Thus, lead time for delivery of bearings would change from 180 - 210 days to 300 - 400 days effective immediately, and profit margin per bearing would be increased. Subsequently, NTN stated it was committed to continue as a supplier of U.S. Navy NT-3 bearings but would no longer retain an inventory of NT-3 bearings. The price of NT-3 bearings would continue to increase. NTN intended further to no longer provide quotes or supply NT-3 bearings in small quantities. Essentially, this means that NTN now provides bearings only to the Navy's spare parts control center and not to shipyard overhaul shops or equipment manufacturers.

PROPOSED SOLUTIONS

The U.S. Navy investigated alternatives to the current situation because of the general lack of interest by domestic industry in manufacturing the special noise-tested bearings. The following is a list of some of the alternatives considered:

- o Construct special storage facilities and stockpile a 3-year supply of noise-tested bearings to act as a buffer against the sudden loss of the foreign source.
- o Upgrade the technology and/or machinery of one or more domestic manufacturers to enable them to make better-quality bearings.
- o Purchase calibrated anderometers for interested manufacturers. The anderometers would be identical to the test machine used by the Navy and would be used by the manufacturers to screen the bearings prior to submitting them for acceptance tests.
- o Guarantee payments to the manufacturer sufficient to justify his operation of a manufacturing facility dedicated only to manufacturing quiet bearings.
- o Finance the development and construction of a completly new facility dedicated to the manufacture of quiet bearings.
- o Investigate more thoroughly the use of high-grade domestic bearings, such as ABEC 7 grade or better, in satisfying the noise levels of the Navy specification. While experience

indicated the possibility that the ABEC 7 grade bearings might satisfy the noise requirements, these bearings are as difficult to obtain from domestic manufacturers as the noise-tested bearings.

- o Develop more specific guidance and criteria for domestic industry to aid them in manufacturing the noise-tested bearings. The results of Navy studies of the NTN bearing may provide the basis for new specific guidance for domestic manufacturers.
- o Explore the possibility of the foreign source constructing a domestic facility to manufacture and store the noise-tested bearings.

Independent of the above alternatives, the U.S. Navy maintained a mobilization agreement with Fafnir Bearing Company that could be activated in the event of a national emergency.

USER'S CONCERN

A meeting was held on December 12, 1983, by a subcommittee of the work group to receive a recent view of the users of quiet ball bearings. At the meeting users were represented by Electro Dynamic Facility of General Dynamics, Hansome Energy Systems, and Worthington Division. It was noted that at the present time the Navy is involved in an intense program aimed at establishing a reliable domestic manufacturing source for quiet ball bearings. Under Title III of the Defense Production Act, the Navy solicited bids for a multi-year quiet bearing supply from domestic sources. Several companies responded with bids, but their capabilities had still to be proven. Concurrently, the Navy was purchasing a 2-year stockpile of quiet bearings from NTN. If additional suppliers entered the business, an already small market would be more finely divided. This would increase prices. Properly preserved, bearings can have a long shelf life. There is a possibility that the market will increase because surface ships now require quiet bearings for chilled water pumps, some sea water pumps, and fire pumps. There could be some backfit for older ships.

Manufacturing quiet ball bearings is more an art than a science. The surface finish is most important. One manufacturer has employed blind people because they have a "fine feel" for surface finish and small tolerances.

There is uncertainty about who will produce the balls for the quiet bearings. At one time, Hoover manufactured the balls for all the quiet bearing manufacturers. It was mentioned the Navy could stimulate domestic interest in quiet ball-bearing manufacture by seeking to purchase a 10-year supply. This would cost about $30 million. Electric motor manufacturers keep a 1-year supply of the most frequently used bearings in stock. In England, RHP manufactures quiet ball bearings but no angular contact bearings, and there have been quality control problems. NACHI in Japan also manufactures quiet bearings except angular contact bearings. Hansome, a motor manufacturer, does some

grinding in the installation of quiet bearings in electric motors. Overhaul of submarine components requires installation of new quiet ball bearings, by specification.

There is a possibility that fewer bearing types could be used if bearing loads could be increased by 20 percent. Such a potential increase in the range of load would reduce the number of standard sizes but might require new materials and steel processing.

The bearings require close tolerances for installation. Sometimes closer tolerances than recommended by the ball-bearing manufacturer are needed for installation in a housing. The angular contact bearings most difficult to install. Some bearings and housings must be ground to meet tolerance requirements. The ball-bearing manufacturer reserves the best equipment for the bearings having the largest sales volumes.

Generally, if bearings pass the anderometer inspection device, they will pass the noise test; but the anderometer test is very sensitive. In some cases, the hardness of the water, where water is used as a cooling fluid, will affect the bearing performance in the test since hardness of water can influence cooling performance and time to reach equal temperature of all parts. There have been some cases, about 1 in 5 and up to 1 in 10, where the bearing passed the anderometer test but the motor failed in the noise test. In these cases the unbalance of other rotating parts may have caused the failure in the noise test. The quiet bearings have on occasion reduced fluid pulsation in pumps.

ASSESSMENT OF CAUSE AND EFFECT

It may not be possible to identify a single cause or the reasons for withdrawal of the U.S. bearing manufacturing industry from the Navy quiet ball-bearing market. By their own statements, it is clear that the U.S. ball-bearing manufacturers had lost money selling these bearings for the same price as the Japanese manufacturer. The manufacturing process requires high accuracy and many quality control steps. There are also many different types and classes of bearings, and the quantity of each is small. The total business of the Navy quiet ball bearings is not large and this may be a major reason for U.S. manufacturers no longer bidding on Navy quiet ball bearings.

Nevertheless, there is agreement that productivity of U.S. manufacturers has lagged in the last 15 years and may have contributed to the withdrawal of domestic producers from the NT-3 bearing market. Indeed, the lag in productivity and the fact that U.S. manufacturers are not competitive with foreign manufacturers have been observed and analyzed for many commercial products. The long downtrend in the rate of productivity in the United States started somewhere between 1965 and 1968 which corresponds to the onset of the withdrawal of domestic manufacturers from the quiet ball-bearing market. A relationship between this correspondence is not likely to be accidental. From 1950 to 1965, the rate of growth of labor productivity in the private business sector averaged 3 percent in a year, but from 1965 to 1973 it slipped to 2.13 percent a year, and from 1973 to 1981 it collapsed to 0.64 percent annually. There are reasons to think the decline was partly due to a slowness in innovation and technical change. Two pieces of evidence can be cited. The number of patents granted to U.S. citizens fell to 37,000 in 1980 from a peak of 56,000 in 1971, and the ratio of research and development expenditures to gross

national product fell to a low 2.2 percent in 1978 from 2.9 percent in the 1960s. But this evidence is not definitive in fixing the blame for declining productivity on a depletion of possibilities for innovation.

Another cause of lagging productivity could have been the oil price explosions in 1973 and 1979. Up to 1973, energy use was rising at 1.92 percent a year relative to all the other factors that go into increasing output. Traditionally, many U.S. manufacturers use tools, fixtures, and processes requiring more energy than is used in some foreign countries. Other explanations of the slowdown in U.S. productivity growth in the years 1965-1981 include these: The rise in government regulation, a decline in work effort, a declining ratio of capital to labor, and the instability of the economy as a whole.

If they continue, high real rates of interest, supported by large budget deficits and inadequate saving rates, could put a drag on capital investment in new plant and equipment, research and development, and investment in "human capital" through educational outlays. These factors will continue the downward pressure on productivity. If there is a nonspurious relationship between declining productivity and withdrawal of domestic manufacturers from technology-sensitive products such as NT-3 ball bearings, then such a prospect spells continued dependence of the Navy on a foreign supplier for critical parts.

Because of their critical function, the quiet ball bearings require the maintenance of the source of supply. This source of supply is not in jeopardy at this time, but there can be a risk of interruption of supply. There is also a question as to which other sources and countries the foreign vendor may sell the same quiet bearings. There is a continuing large effort to reduce noise in machinery components to be installed in submarines. Thus, noise reduction in bearings becomes very important because the bearing could become the noise-limiting element in the machinery component. The historical instability of the U.S. Navy shipbuilding programs also affects component manufacturers. Contractor investments in manufacturing facilities involve high risks, and the present high interest rates will further limit the implementation of improved manufacturing technologies. DOD has some programs to provide incentives, including the Manufacturing and Shipbuilding Technology Program (MT/ST) and the Industrial Modernization Incentives Program (IMIP).

The Navy is interested in competition and standardization, but the two are not very compatible. Competition for the lowest price of quiet ball bearings may not be the optimum objective for the Navy. Also, quicker, shorter decision-making apparatus in the Navy for changes and deviations may aid productivity. Finally, it must be considered that quiet ball bearings require an input of high technology, and no research for new approaches in technology for the quiet ball bearings has been done in a long time. Today, there are a large number of new and improved steels and other metals available, as well as new composite materials, some of which have a higher modulus of elasticity and higher strength of materials than the steel now being used. There are new concepts in lubrication and new manufacturing methods which could

be used for quiet ball bearings. This could lead to entirely new technical concepts for quiet ball bearings and may eventually lead to improved bearing quietness and vibration performance.

In addition, it may be desirable for the U.S. Navy to initiate a study to determine why so many different types of bearings are in use. This should be followed by appropriate steps to reduce the large number of different types of bearings by a substantial amount. This will not only reduce first costs of the bearings by increasing the number of the remaining types but will also simplify and reduce costs of logistic support for the components aboard ships which have the quiet bearings installed. The implementation of such ideas will require new approaches and imagination for the vendor, the shipbuilder, and the U.S. Navy.

CONCLUSIONS

The procurement of quiet ball bearings is an example of how a specific naval component over the last 20 years has developed into dependence upon a single foreign vendor. It is possible that continued dependence upon that vendor for quiet bearings could jeopardize the maintenance of the low noise profile of the Navy's submarine fleet should that vendor cease to supply the quiet bearings. It has also been indicated that this case is not limited to Naval quiet ball bearings but similar events have occurred in commercial and other naval components. Therefore, this case can be considered generic and it may be related to low quantity of production and to the general decline in productivity.

A case study of noise quiet bearings has elucidated many of the general economic conditions and other pressures that have shaped the Navy vendor industry in the last decade. Practically no research in either technology or manufacturing methods has been done for quiet ball bearings. The solution of the problem has been researched by the U.S. Navy and a number of suggestions for the remedy have been made. To these should be added an innovative research program in both technology and manufacturing methods.

ADDENDUM

Under title III of the Defense Production Act, the Navy in 1984 guaranteed the purchase of nearly $1 million of quiet bearings in one year, in addition to the cost of the product, and was then able to contract with domestic companies for the manufacture of quiet ball bearings.

APPENDIX C

REVIEW OF GOVERNMENT R&D AND RELATED PROGRAMS DIRECTED AT SHIPBUILDING

NATIONAL SHIPBUILDING RESEARCH PROGRAM

The structure and contributions of the National Shipbuilding Research Program with its partner the Ship Production Committee of the Society of Naval Architects and Marine Engineers (SNAME) were described in the committee's first-year report (National Research Council, 1982). Since that time, a number of initiatives have been undertaken to strengthen the program and to target it to Navy needs to a greater extent. A long-range plan has been completed which continues the current basic format of the National Shipbuilding Research Program and the advisory relationship of the Ship Production Committee. The plan establishes the program goals of reducing the labor hours and construction time of shipbuilding and repair by one-third within 5 years, and, in 10 to 20 years to regain competitive status internationally.

To achieve this, the plan calls for continuing the R&D program supported by the Navy and the Maritime Administration with in-kind assistance from participating shipbuilders. The development of a body of commercial shipbuilding standards is to be continued and accelerated. Suppliers, including combat systems suppliers, are to be brought into the program. And, the program is to be coordinated with the Navy's Manufacturing Technology (MT) program and Industrial Modernization Incentives Program (IMIP).

Regardless of whether one considers that the resources and activities of the National Shipbuilding Research Program are sufficient to achieve the program's goals, the fact remains that the National Shipbuilding Research Program is the primary focus of technical exchange and cooperation in the shipbuilding industry. As the committee noted in its first-year report, the program stimulates applied research, fosters technical communication and exchange among shipyards, enhances the incorporation of productivity improvements into shipyards, and promotes communication of shipbuilding industry requirements to industrial suppliers (National Research Council, 1982). Thus, important benefits result from the process of technical interaction among shipbuilders in the program in addition to the substance of the activities undertaken.

MANUFACTURING TECHNOLOGY IMPROVEMENT

The Manufacturing Technology (ManTech) program within the U.S. Department of Defense (DOD) promotes advances in manufacturing technology. It concentrates on the validation and application of new and improved production technologies. It shares with industry the risks and costs

of introducing, adapting, and applying developed advanced technologies, which have been proven in experimental or industrial settings. Mantech projects introduce new processes or technologies; they provide initial demonstration to industry with the expectation that industry will expend capital for subsequent installation.

ManTech projects define particular technologies to the point at which they are repeatable and reliable, with the expectation that manufacturers will then purchase and use them in volume. ManTech projects are nonproprietary; diffusion is, in fact, encouraged by requirements that the contractor make a disclosure of technical findings and implementation results as well as license the processes developed on a non-exclusive basis (i.e., all data rights are government property). The fact that the program does not result in proprietary advantage has worked against industry participation in the program.

Figure C-1 shows the Navy ManTech budget in comparison to that of other services. While the sums in the table are significant, the Navy

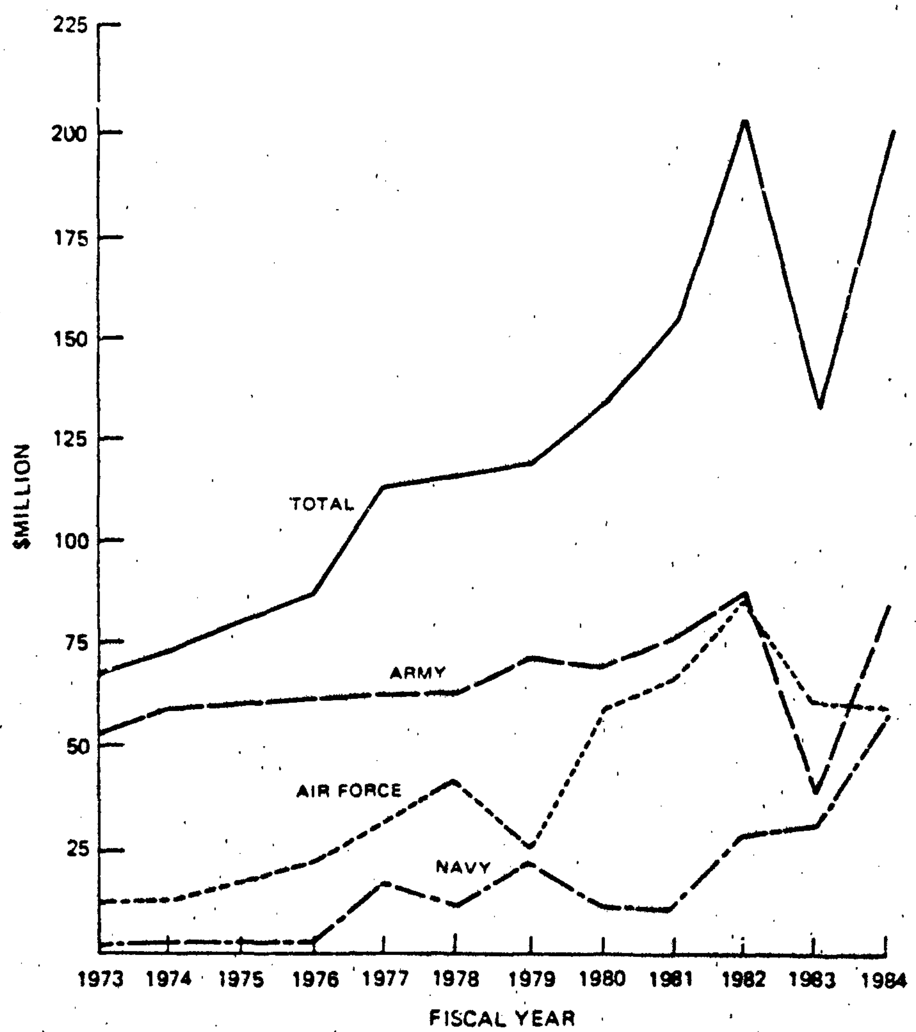

FIGURE C-1 Manufacturing Technology Program Funding ($ Million)

SOURCE: U.S. Navy.

considers them inadequate to bring about significant productivity or technology changes in the shipbuilding industry. To gauge the limitations of the current funding level, consider that about $50 million in fiscal year 1984 ManTech funds directed to the Navy was apportioned among the Naval Air Systems Command, Naval Electronics Systems Command, Naval Supply Corps, and Naval Sea Systems Command (NAVSEA). Of the $13 million received by NAVSEA, about 20 percent went to support the National Shipbuilding Research Program of the Maritime Administration, about $6 million was directed to combat systems, and the remainder, $3 million to 4 million, was awarded directly to shipbuilders and their suppliers.

The DOD's ManTech program uses conventional procurement terms and procedures. Contracts are negotiated on fixed price or cost plus basis. The majority of ManTech projects have been awarded to prime contractors (shipbuilders in the case of shipbuilding projects).

The lead times for ManTech projects do not vary significantly from those for ordinary purchases. A decision to pursue a technology may precede a request for a proposal by as much as 3 to 5 years. These long lead times for ManTech projects seem self-defeating, in view of the program's purpose of promoting advanced technology. Like other parts of the DOD budget, ManTech budgets must be assembled at least 2 years in advance of contract awards. This means that the program is considerably handicapped in its ability to promote rapidly changing manufacturing technology.

ManTech initiatives have in the past been project-based and technology specific. Within the past few years, the Navy and other services have developed a complementary weapons-system and plant-based approach to manufacturing technology improvement. Within the Navy, this strategy is termed the Industrial Modernization Incentives Program (IMIP).

IMIP is a strategy of government/industry joint venture, which encourages industry through contractual incentives to increase capital investments, primarily with their own financing. The IMIP encourages productivity improvements in all facets of management, engineering, and manufacturing. The principal technique of the IMIP is productivity-shared savings rewards that permit industry to share in the cost reductions (i.e., program savings) resulting from productivity enhancing capital investments and the use of savings to recoup capital formation investments. The contractor's investment also is protected by a government cancellation guarantee. IMIP is intended to reach the supplier industries directly and flow down through the prime contractors, i.e., the shipbuilders. A typical IMIP strategy incorporates three phases, which may be negotiated separately. In the first phase, DOD requires a comprehensive analysis of the status and productivity of the contractor's production facility (the Mantech program has funded some of these facility assessments). In the second phase, DOD supports the advanced development of identified technologies and the design of plant improvements. Finally, the contract undertakes to purchase and install the new equipment. The costs of t[illegible] application may be recovered from the anticipated lowered program costs as the result of the innovation. An IMIP project [illegible]y be initiated either by DOD acquisitions personnel or by a contractor.

Although it originated independently, IMIP can be and has been viewed as a means of ensuring the implementation of ManTech project results or of promoting other advances in the state of the art. IMIP can, however, result in the adoption of off-the-shelf though technologically advanced equipment. The relationship between ManTech projects and the IMIP is shown in Figure C-2.

The objectives of IMIP projects are to reduce costs, to increase surge capacity, or to improve product quality and performance. IMIP contracts are preferred with prime contractors, with flow-down through agreements between prime contractor and subcontractor to second-tier component manufacturers. DOD policy encourages this "pyramiding," out of the realization that subcontracted component systems often represent more than half of the cost of a weapons system and out of concern that second and third-tier suppliers are frequently fragmented, have poorer access to capital markets, and therefore have greater difficulty than primes or major subcontractors in obtaining capital for investment in modern plant and equipment.

The general aim of these and other measures is to provide incentives for contractor investments through greatly increased returns on investments and by providing the contracts with investment protection in the event of the cancellation of the procurement programs for which the investments are made. However, the potential contribution is overshadowed by the effect of Navy acquisition policy on supplier investment in productivity. In addition, the ManTech and IMIP programs have received mixed reviews by those involved in them.

- A Navy survey found that many defense contractors are prepared to modernize their facilities when contractual incentives and long-term stability provide a viable base for business investment. When these conditions do not prevail, contractors seek direct government funding support for plant modernization.
- No IMIP projects have yet been implemented by shipbuilders.
- Electronics and combat systems suppliers appear to be better candidates for the IMIP than shipbuilders because of their more stable business base, which is characterized by multi-unit orders and multi-year funding commitments. Recently, in fact, NAVSEA has focused its test IMIP involvement to combat systems manufacturers.
- The government may have some difficulty in providing contractor protection against program cancellation or stretchout unless existing acquisition regulations on this subject are modified.

It would appear from the above that weapons and electronics systems suppliers have more opportunity to benefit from DOD's ManTech and IMIP programs than shipbuilders and H,M&E suppliers because of the greater participation in these programs of weapons and electronics prime contractors, than shipbuilders.

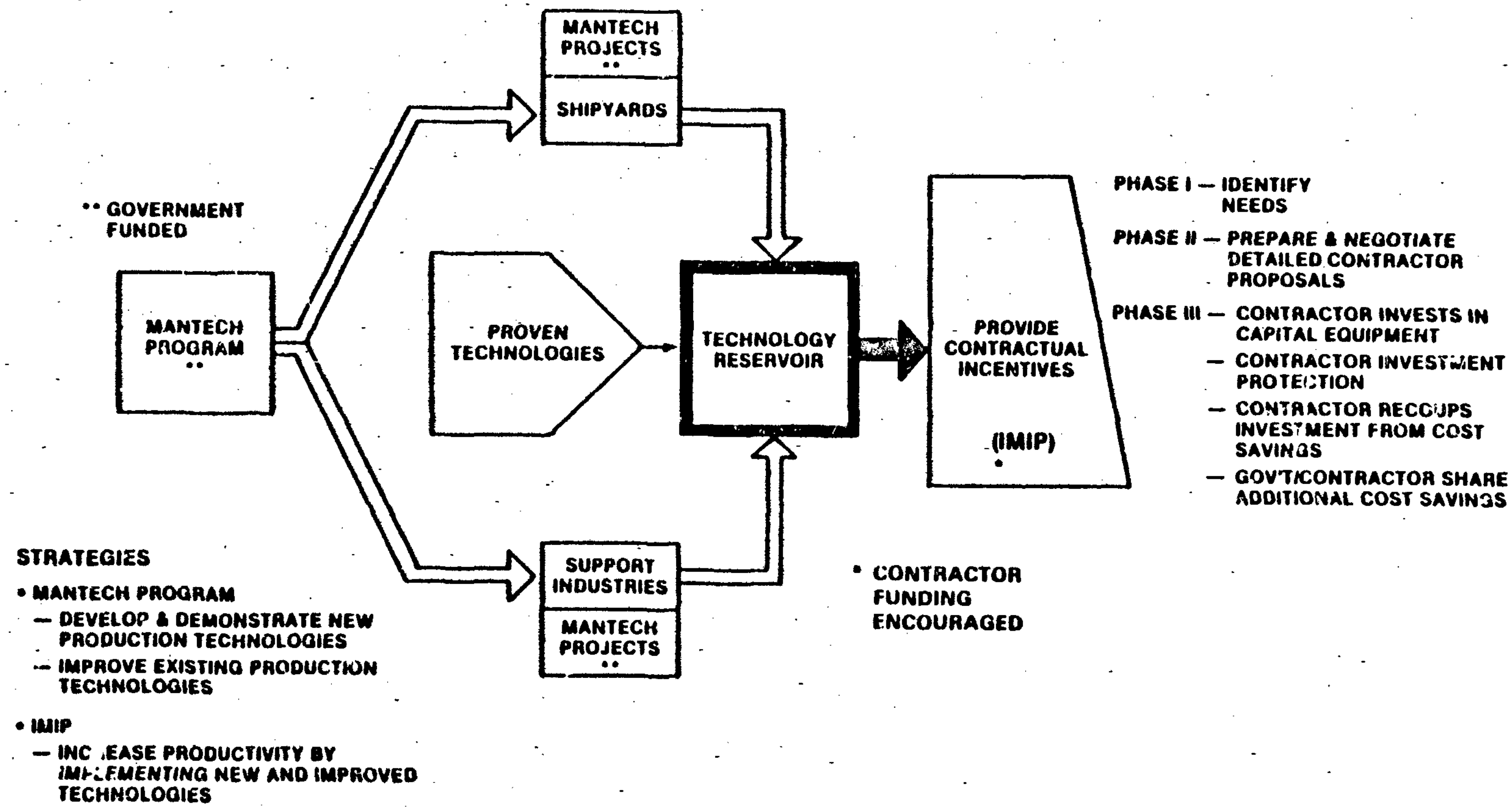

FIGURE C-2 IMIP & Manufacturing Technology Program Interface

SOURCE: U.S. Navy.

AIR FORCE INTEGRATED COMPUTER-AIDED MANUFACTURING PROGRAM

Program Description

In the mid 1970s, the Air Force established the Integrated Computer-Aided Manufacturing (ICAM) program to foster and promote improved productivity in military aircraft manufacturing. The ICAM program has employed a cooperative industry and government strategy in which the government has provided project funds and program direction while industry has developed, approved, and implemented projects through a well-developed advisory and participant structure. Funded in recent years at a level of $80 million, the ICAM program has become the major national focus for manufacturing technology improvement for batch manufacturing, and for addressing the unique aspects of defense manufacturing, which typically consist of relatively small numbers of complex or difficult to manufacture items.

The ICAM program has addressed both the definition and design of integrated manufacturing systems and the application of computers to provide information links and planning and control functions where economically feasible. Within the ICAM program, integrated manufacturing is defined to include: self-optimizing system with respect to utilization of resources; set of modular system components; current, accurate, and efficient base of data; control structure which can accommodate various management strategies; and, an applications structure which reduces the problem of the cumulative effects of manufacturing reliability. Integrated computer-aided manufacturing systems are not necessarily completely automated systems. The difference between an integrated system and the conventional applications of computers is in the capability of an integrated system to take advantage of the commonality of the information and functions which each of the individual systems requires. An integrated manufacturing system eliminates nonessential transformation and reconfiguration of data.

To implement such an integrated system, the ICAM program recognized the need to establish an architecture of manufacturing that defines the systems used to produce a product. The method used is named IDEF--the "ICAM Definition" method. IDEF is a modeling methodology whose purpose is to graphically capture characteristics of manufacturing.

The ICAM system development methodology is unique because it establishes a formal definition of a current manufacturing system prior to the specification of the future integrated system and it uses a modeling rather than a specification approach to accomplish this definition.

Important to the ICAM program has been effective communication among the Air Force and aerospace manufacturers. Manufacturers participated in the all-important development of architecture and also in subsequent new system development and implementation efforts. In several cases, program participants were licensed by the Air Force to market commercially systems developed under the program. There was much concern at the outset whether industry-level architecture could be developed for the diverse manufacturers that would be both representative and meaningful. Owing in part to the adoption among

participants of a posture of "Can you live...?" as a nonopposing but also nonabstaining position, the ICAM progam has produced collectively valid architecture and focused on important areas for system development (Softech, Inc., 1980).

Program Relevance to Shipbuilders

Development of an industry-level architecture describing shipbuilding would serve similar purposes as the ICAM architecture it would provide a basis for understanding and communication among industry and government program participants. What is not known is the extent to which an industry-level architecture of shipbuilding would be both representative and meaningful because of the diversity of products, production processes, and technologies employed.

The usefulness of the ICAM definition method applied at the level of the shipbuilder is more readily grasped. These models could serve as targets for evolutionary systems development and acquisition and provide a viable baseline for system integration planning. Additionally, if the functional models were sufficiently detailed and could be adapted as stochastic models, they could serve to perform simulations to analyze production schedule viability, shop and manpower loads, change order impacts, late material impacts, new contract impacts, and improved methods impact, for example. Thus, while the products of the ICAM program are related to aircraft construction, the structure of the program can be applied to other industries, including shipbuilding. The developers of the ICAM architecture have already undertaken some production process analysis work for at least one shipbuilder.

NAVSEA INFORMATION SYSTEMS IMPROVEMENT PROJECT (ISIP)

NAVSEA has two major missions. to acquire naval ships and to provide logistic support for them. The organization of NAVSEA is based on the principle of providing life-cycle management of each ship from initial definition until the end of its service life.

From the standpoint of information management, this is a unique task because of the large amount of engineering data associated with a ship, the number of ships, and because of the length of time that the ship's data base needs to be maintained. The design and construction process that generates these data may occupy 10-15 years. Once in the fleet, a ship remains in service nominally for 20-30 years and historically sometimes longer. Thus, naval ship data are used, and need to be maintained and updated for 40-50 years after the data are created (a case in point is the battleships of the 1930s, which have recently been modernized for the fleet of the 1980s). This spans several generations of computer equipment.

NAVSEA's data management task has an even more complex dimension because large quantities of graphic and statistical data and other

documentation have to be transferred between private shipbuilders and suppliers and the Navy to enable ship construction and at other times during the life of a ship. The necessity of data transfer raises two major concerns. NAVSEA has a substantial interest in the ease and cost of data transmission, and in procedures for configuration control.

The great majority of NAVSEA data today is on paper. However, in 1983, a project office was established and charged with responsibility to manage the conversion from a paper-based technical data system to a computer-based technical data system. The project office also has been assigned the responsibility for managing the computer-aided design/computer-aided manufacturing (CAD/CAM) program of the Naval Material Command.

The Information Systems Improvement Project (ISIP) within NAVSEA will provide in the future a focus and source of direction for the introduction and use of computerized systems in shipbuilding and life-cycle ship engineering support. ISIP has already developed draft specifications for acquiring data in computer-sensible form equivalent to drawings and other technical data. The specifications make use of the initial graphic exchange specifications (IGES), an American National Standards Institute (ANSI) standard developed under the aegis of the National Bureau of Standards.[1]

The ISIP is also directing a major acquisition of computer graphics systems for use by NAVSEA. Decisions made by the Navy about computer graphics equipment, means of transferring electronic data, and other acquisition issues, are likely to have a large influence on the shipbuilders' decisions in these areas. Thus, it is extremely important that there be good communication between the Navy and its shipbuilders and shipbuilding suppliers in this rapidly developing area.

NATIONAL SHIPBUILDING STANDARDS PROGRAM

The National Shipbuilding Standards Progam (NSSP) is a concerted attempt by the shipbuilding industry, with government participation and support, to develop a complete and usable set of shipbuilding standards.

The program is coordinated by ASTM Committee F-25 on Shipbuilding, a committee formed in June 1978 by a group of individuals representing shipyards, owners, design agents, suppliers, regulatory agencies, the Maritime Administration, and the U.S. Navy.

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[1]The IGES specifications have not been developed specifically for shipbuilding applications (National Research Council, 1983). An initial phase of IGES testing by the Navy, a design agent and three shipbuilders has recently been completed. While test results documented less than full compliance by CAD/CAM vendors' software, the test resulted in vendors' promises of full compliance (VanderSchaaf, 1984).

Among the 10 active panels of the SNAME Ship Production Committee is Panel SP-6 on Standards and Specifications. Panel SP-6 has a mandate to act as the U.S. shipyards' steering committee for the NSSP. Its duties are to develop plans and priorities for the development of standards and to recommend cooperative projects which are cost-shared by industry and the U.S. government which will benefit all U.S. shipyards. SNAME Panel SP-6 works closely with ASTM Committee F-25 on Shipbuilding. While it is SP-6's function to provide lists of standards that should be developed and the funding to prepare draft standards for consideration, it is ASTM F-25's duty to process the draft standards through the established ASTM procedures and to ensure that the resulting standards are impartial, effective, usable, and acceptable to all affected by their implementation. The committee also assures that they are truly consensus standards, which have been reviewed and accepted by everyone who has an interest.

SNAME Panel SP-6 and ASTM Committee F-25 on Shipbuilding, working together within the NSSP, have adopted a long-range plan (IHI, 1982). Successful implementation of the long-range plan will require long-term commitments and continuing thoughtful and creative management. The long-range plan presents a road map and a set of priorities and specific objectives which are the stepping stones to the development of a complete compendium of U.S. shipbuilding standards (DeMartini, 1983).

At the Navy's request, to provide to the Navy shipbuilding program, a high priority has been given by SNAME Panel SP-6 and ASTM Committee F-25 to the conversion of existing MilSpecs and other Navy standard documents to commercial industry standards. The Navy has more than 4,000 MilSpecs and 3,500 standard drawings. The MilSpecs cover virtually everything used on board ship from propulsion turbines and generating equipment to communications gear; from complex electronic components to simple hull fittings, many of which do not have military requirements. In addition, many of these MilSpecs and other documents are out of date and have fallen into disuse.
Sometimes their use results in items costing more than the commercial equivalent which would perhaps serve the purpose as well. Because of their numbers and diversity, the task of updating, revising and converting them is monumental.

ASTM Committee F-25 has created an executive subcommittee, F-25.94, to coordinate the coversion of U.S. Navy MilSpecs and other standard documents to commercial standards. This subcommittee will work closely with SNAME Panel SP-6 and the Navy standards group. The procedure for updating MilSpecs will work as follows. The Navy will forward candidate MilSpecs to SNAME for review and comment by interested members of the technical community. The comments obtained will be forwarded to ASTM. ASTM will translate the data into ASTM format and issue them as ASTM standards which will then be updated every 5 years. The standards will be available for use by the Navy and others.

OTHER NAVY INITIATIVES

While ISIP takes the long-term, global view of computerization, NAVSEA also has the more immediate task of developing contract specifications concerning computerization for new ship contracts. A computer-supported design office within NAVSEA is developing mechanisms for transfer of digital design data, employing IGES specifications, and seeks to tie new contract requirements to state-of-the-art capabilities. Several new shipbuilding contracts already require that the shipbuilder provide selected record drawings (the 5 percent of all detail design drawings that are kept by the Navy for the life of the ship) on magnetic tape in IGES format.[2] In the not-too-distant future, shipbuilding contracts may require that data be kept in computer sensible form and electronically transmitted among users. Shipbuilders need to take this important new thrust into account in introducing computers into ship production.

The most fundamental and far-reaching Navy initiative is to provide greater reward to the shipbuilders and suppliers for improvement by means of increased profit (this subject is discussed in chapters 3, 4, and 8).

[2]Engineering change proposal on the LHD 1, dated June 4, 1984. Similar requirement in draft DDG 51 contract specifications.

APPENDIX D

CASE STUDIES OF CAPITAL IMPROVEMENTS IN THE U.S. NAVAL SHIPBUILDING INDUSTRY[1]

TODD SYNCROLIFT- 1979-1984

In 1984, Todd completed acquisition and installation of a syncrolift at a cost of about $40 million. Measuring 655 feet by 106 feet, with a lifting capacity of 48,000 dwt, the syncrolift enables Todd's Los Angeles division to repair or overhaul five maximum size ships ashore at one time. As early as 1979, Todd Los Angeles recognized that extensive rebuilding must be undertaken during the next 10 to 20 years to replace aging and outdated facilities. After assessments of opportunities and alternatives, Todd Los Angeles proposed installation of a ship lift and land level transfer facility which would be built on 30 acres of a 104 acre parcel of land and water leased from the Los Angeles Harbor Department. A marketing study conducted in support of this decision was was based on the analysis of available U.S. Navy planning documents, known new ship construction schedules, deliveries, post shake-down availabilities, and a profile of the types of ships in the Pacific.

After studying the Navy planning documents for the existing fleet, and new ship types, and with some assumptions as to the Naval ships that would be on the scene through the mid 1990s, pro forma income statements were prepared assuming varying levels of utilization. These indicated that the ship lift would be an economically feasible undertaking for a mix of naval repair, overhaul, and new construction. The study indicated that a two-berth syncrolift would produce significant returns on investment provided that Todd is able to obtain long-term Navy work. A life-cycle maintenance contract for FFGs in the Pacific is particularly important in this respect. The project was paid for with corporate cash, which resulted from Todd's series production of 11 FFGs.

Three points are especially pertinent to the analysis of capital formation:

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[1]The case studies, which are summarized in this appendix, appear in their entirety in the committee's working paper on capital formation.

- The syncrolift is justified on the basis of increased capability for repair and overhaul work to a greater extent than new construction. This reflects economic realities in the shipbuilding industry.
- Todd is counting on keeping the facility busy with Navy business. Todd has invested $40 million to position itself for this business without any advance commitments or assurances, or Navy financial assistance.
- Todd was able to purchase the syncrolift with corporate cash as opposed to debt financing. This enviable position is the direct result of cost savings and profits from the multi-ship, multi-year series construction of FFGs for the Navy.

MARINETTE--EXPANSION OF CAPABILITIES TO INCLUDE ALTERNATIVE HULL MATERIALS, 1983-1984

Marinette Marine Corporation for the past decade has concentrated on the construction of auxiliary vessels up to 300 feet, preferably in quantities of two or more, primarily for the U.S. Navy. The rationale for this business strategy was that procurements for these size ships were usually restricted to small businesses; large shipyards were not pursuing this market, nor were they competitive; small shipyards were reluctant to expand capabilities to the larger than boat-sized vessels; and the U.S. Navy Five-Year Defense Plan included significant requirements for vessels of this size.

In 1983, the directors of the corporation decided to develop new erection facilities for wood and glass-reinforced plastic construction to enable participation in the construction of mine countermeasures ships for the Navy. Mine countermeasures ships with non-metallic hulls constitute a significant share of the naval auxiliaries market, and continued demand (as evidenced in the Navy's Five-Year Defense Plan) appears solid. The decision to expand corporate capabilities with new facilities, as opposed to using existing facilities, was made because utilization of existing shops would have caused abandonment of traditional metal auxiliary and service metal markets for the duration of the mine vessel programs (i.e., 5-10 years). Re-entry to these markets, including the redevelopment of a work force skilled in steel fabrication, would be difficult after that period of time. In addition, while a significant market for wooden vessels beyond mine countermeasure ships appears nil, additional markets for glass-reinforced plastic construction may well develop that would overlap or complement targeted metal construction programs.

It is important to note that the corporate decision to expand its construction capabilities to alternative materials was made in anticipation of market demand, to position the company to capture potential new business. There was no Navy involvement in this decision other than the opportunities the Navy programs present. Continued funding of these multi-year programs is a major corporate concern.

NEWPORT NEWS SHIPBUILDING AND DRYDOCK COMPANY- LAND LEVEL SUBMARINE FACILITY

In fall 1983, Newport News Shipbuilding and Drydock Company (NNSDCo) announced plans to construct a $350 million land-level submarine construction and overhaul facility. The new plant was technologically necessary to remain competitive or superior in the submarine construction and overhaul business (the competitor, Electic Boat (EB), already constructs submarine hulls in a land level facility). The investment was justified on the basis of anticipated Navy business. In December 1983, however, the Navy awarded one of two new attack submarine construction contracts to NNSDCo's competitor. Shortly thereafter, NNSDCo announced that it was delaying its planned investment until business conditions warranted it. This sequence of events graphically illustrates the effect of Navy acquisition decisions on capital investment for modernization of the shipbuilding industry.

NEWPORT NEWS SHIPBUILDING AIRCRAFT CARRIER CONSTRUCTION FACILITIES

Newport News Shipbuilding has a long history of involvement with the U.S. Navy's carrier program. The construction of the CVN71, authorized by Congress in the fiscal year 1981 budget, was originally planned for a World War II-era dry dock, the construction site for previous Nimitz class carriers. A preliminary study indicated significant savings in construction time if the North Yard facilities could be employed. The North Yard is a $250 million facility constructed in the early 1970s for the construction of ultra-large crude carriers and liquefied natural gas carriers. The investment in the North Yard was made based on the expectations inherent in the Merchant Marine Act of 1970, and an optimistic forecast of a growing demand for imported gas and oil. The intended markets for the North Yard never matured for reasons that are well known and need not be recounted here.

The advantages of using the North Yard stem from its modern production facilities, which include automated steel plate receipt and handling system, automated steel production facility, ample dry dock surrounded by platen space and supporting shops, and service by a 900-ton gantry crane and other cranes.

To use the North Yard, the ship structure would have to be modified to take advantage of the Steel Production Facility (SPF) and the heavy lift capacity of the 900-ton gantry crane. Extensive preoutfitting was possible, provided machinery and equipment could be delivered up to 2 years earlier than normal. In addition, there would be the monumental engineering task of reconfiguring the ship and its documentation.

The decision was made to use the North Yard for the CVN71 and a crash program in all affected yard divisions to accomplish this plan was started. Engineering tasks were greatly facilitated by a $5 million investment in computer-aided design equipment (a 60-terminal system). The CAD investment is justified on an average 3 to 1 savings in drafting time.

The yard is adding another 60 terminals to this system in 1984-1985, and is developing integrated advanced computer-aided design/computer-aided manufacturing systems.

The additional capital investment necessary to economically construct CVN71 in the North Yard amounted to $60 million. The major items and investments, totaling $60 million, were: outfitting berths, $20 million; test steam barge, $16 million; added cranes, $8 million; DD12 certification modifications, $5 million; intermediate gate, $5 million; dredging, $3 million, and miscellaneous, $3 million.

In addition to these investments, advances in work practices were necessary in order to obtain the advantages of the North Yard. Two practices which were not especially important when using smaller units were dimensional accuracy and welding progress. Inaccuracies in the cutting of plate and the fabricating of parts were acceptable. Parts usually were made oversized and then trimmed to fit. Subassemblies could be partially welded, lifted aboard ship, and finish-welded when convenient.

However, the large sections and the use of the automatic equipment throughout the North Yard processes required close tolerances. Fit-ups had to be accurate to use the equipment and machinery in the North Yard. The larger units would have to be completely welded at ground level so that they would be strong enough to withstand the lift to their position in the dry dock. The welding requirement could be solved by closely scheduling the fabrication of subassemblies so that they would be completely welded when needed. The required degree of plate-part accuracy could be provided by using computer-generated NC cutting tapes to fabricate the structural parts.

The ship's construction is well along and on schedule with its launch of October 27, 1984, to occur in 17 months less construction time than the CVN70. Newport News expects that the two follow-on carriers, the CVNs 72 and 73, will show further schedule improvement as not every improvement could be applied to the CVN71 because of short lead times.

While the economics of the added investment in the North Yard to build the carrier are favorable, the big winner is the government. The Navy has calculated that it will save $100 million on the CVN71. Savings on the CVN72 and 73 are estimated by the Navy to total $750 million, taking into account the effect of multi-ship procurement, and still earlier deliveries.

NATIONAL STEEL AND SHIPBUILDING COMPANY--FLOATING DRYDOCK

Until 1982, the National Steel and Shipbuilding Company (NASSCo) pursued a conservative plant investment strategy of first securing an adequate book of business offering sufficient profit potential for investment payback, and then investing capital necessary for contract performance. No major investments were made in anticipation of prospective business opportunities. In 1967, 1973, and 1975, NASSCo was fortunate to obtain multi-ship orders for series production of ships, which enabled this investment strategy. While the ultimate

merits of this capital investment strategy are still to be proven, NASSCo has experienced a significant volume of business, particularly since 1967, earned reasonable profits and returns on investment, and has been a major reasonably stable employer in San Diego, employing a high of 7,600 workers in 1980. Business conditions in the early 1980s however, dictated new plant investment strategies.

NASSCo as a corporation historically has placed greater emphasis on new construction business as compared to repair, machine shop, and foundry activities. New construction has commanded the majority of the company's human and plant resources, and has offered the highest profit potentials. In the early 1980s, the long-term strategic business plan (a company discipline) depicted questionable earnings opportunities in the new ship construction arena. New construction backlog was scheduled to expire in the fourth quarter of 1983; industrywide volume was forecasted to decline, and competition for the few available contracts would intensify. Commercial opportunities appeared scant; congressional legislation implementing a national maritime policy or other favorable actions appeared unlikely to occur. Navy shipbuilding plans, which traditionally favor combatants in the near term, did not offer timely programs suited to NASSCo's capabilities, that is auxiliaries/amphibious class ships. NASSCo's senior management was thus challenged with otherwise securing business volume necessary to maintain the company's core resources.

At the same time, NASSCo's senior management maintained a dialogue with Navy officials concerning their perceived need for expanded repair and overhaul facilities among private repair contractors in San Diego. In particular, the Navy stressed their need for additional drydocking facilities in San Diego.

Senior management concluded from evaluations of other opportunities that expansion in the repair market offered the best potential among the alternatives, as such expansion would provide the largest incremental volume. The recognition of the need to develop other sources of business plus the Navy's influence led NASSCo's president to set in motion in the spring 1982 detailed market and financial evaluations for a floating drydock acquisition. The program that was developed and sold to senior management and parent corporation management was for acquisition of a 25,000-ton floating drydock and attendant repair facilities. Initial estimates set the cost at $25 million, the largest single capital investment in NASSCo's 23-year corporate history. The investment would provide NASSCo the facilities needed to expand its volume of ship repair business, a strategy commanding greater emphasis with the expected downturn in NASSCo's primary business of new ship construction.

NASSCo's timing for presenting the proposal was opportune, in view of depressed conditions in the parent company's traditional worldwide construction contracting business and lack of competing capital investment opportunities. Favorable to the parent company's decision was NASSCo's strong financial performance over the past decade.

Throughout the development and evaluation of the proposal, uncertainties continued to exist respecting the future volume of the San Diego repair market. Questions remain unanswered with respect to

political pressures for employment stimulants in the form of overhaul contracts of San Diego-based ships to other cities. Stated differently, will allocation trends continue in varying degrees "to preserve the industrial base?" Another imponderable concern is the future role of Navy repair yards. Currently, those shipyards operate under congressional statutory constraints, including the percentage of work which can be performed in a Navy shipyard versus a private sector shipyard, and ceilings on total manpower limits on Navy shipyard employment. Changes in these conditions will impact the work available to San Diego area contractors. Also, at the same time that NASSCo developed its plans, other West Coast shipyards both in San Diego and other nearby ports, were upgrading their repair abilities with significant capital investments, in response to the same market conditions that were impinging on NASSCo.

Despite these uncertainties, favorable tax depreciation schedules and CAS-414 imputed interest allowances benefited cash flows particularly in the early years, thereby reducing investment risk and achieving parent company criteria for return on investment. Investment capital for the acquisition was reasonably available, and the funds for the facility were obtained with industrial revenue bonds.

APPENDIX E

COST OF FACILITIES CAPITAL (COFC) EXAMPLE

Assumption: A major U.S. shipyard engaged principally in naval shipbuilding, overhaul, and conversion invests an average of approximately $100 million per year to update its facilities. The reasons for investment cover the upgrading of piers and docks, increased capacity, environmental measures, safety, and advanced technology. Cost reductions as a result of the investment are generally passed on to the Navy as reduced costs.

Table E-1 shows the financial status of the investments for a given year over the assumed 10-year average life for the facilities. Twelve percent is used for Cost of Facilities Capital, although the rate varies depending on the U.S. Secretary of the Treasury determination.

Table E-2 shows the after federal corporate income tax investment economics at the current standard rate of 46 percent. Investment tax credit allowance of $10 million is taken so that $90 million is to be recovered. Columns A through C show the after tax positive cash flow

TABLE E-1 Investment Status ($000)

Year	Net Book Value End of Year	Straight Line Depreciation	Average Net Book Value	COFC @ 12 of Average Net Book	12 % Interest
0	$100,000				
1	90,000	$ 10,000	$95,000	$11,400	$11,703
2	80,000	10,000	85,000	10,200	11,004
3	70,000	10,000	75,000	9,000	10,216
4	60,000	10,000	65,000	7,800	9,329
5	50,000	10,000	55,000	6,600	8,328
6	40,000	10,000	45,000	5,400	7,201
7	30,000	10,000	35,000	4,200	5,930
8	20,000	10,000	25,000	3,000	4,499
9	10,000	10,000	15,000	1,800	2,886
10	-0-	10,000	5,000	600	1,069
TOTALS		$100,000		$60,000	$72,165

TABLE E-2 After Tax (A.T.) Investment Economics[a]

($000)

Year	After 46% Corp. Tax Cash Flow Deprec.	After 46% Corp. Tax Cash Flow COPC	After 46% Corp. Tax Cash Flow Total	Less A.T. Effect of Interest	Difference C − D	19.0% of Book Value = A.T. Income	Total Cash Flow E + F	Present Value Factors @ 12%	Discounted Cash Flow @ 12 %
1	$ 4,600	$ 6,156	$10,756	$ 5,383	$ 5,373	$18,050	$ 23,423	.89	$20,846
2	4,600	5,508	10,108	5,061	5,047	16,150	21,197	.80	16,958
3	4,600	4,860	9,460	4,699	4,761	14,250	19,011	.71	13,498
4	4,600	4,212	8,812	4,291	4,521	12,350	16,871	.64	10,797
5	4,600	3,564	8,164	3,831	4,333	10,450	14,783	.57	8,426
6	4,600	2,916	7,516	3,312	4,204	8,550	12,754	.51	6,505
7	4,600	2,268	6,868	2,728	4,140	6,550	10,690	.45	4,811
8	4,600	1,620	6,220	2,070	4,150	4,750	8,900	.40	3,560
9	4,600	972	5,572	1,328	4,244	2,850	7,094	.36	2,554
10	4,600	324	4,924	492	4,432	950	5,382	.32	1,722
TOTALS	$46,000	$32,400	$78,400	$33,195	$42,205	$94,900	$104,105		$89,677
COLUMN	A	B	C	D	E	F	G	H	I

[a]Not shown is an Investment Tax Credit of $10 million taken in year one.

effect of depreciation and COFC. Column D shows the cash flow effect of interest charges. Column E shows the after tax interest costs and its effect on cash flow. Column E is the difference between the positive cash flow effects of depreciation and COFC and the payment of interest.

It can be seen from the data that COFC payments on the investment are essentially offset by interest payments. To recover the investment and to make a reasonable return, additional cash flows are needed from profits generated by the investment. Only $90 million is to be recovered because of an investment tax credit (ITC) of $10 million. Column F shows the income required to achieve capital recovery. The income required is expressed as a percentage of depreciated book value which calculates to slightly over 19.0 percent. Column G is the total cash flow; Column H the present worth factors for 12 percent; and Column I the discounted cash flow based on an investment hurdle rate of 12 percent. The total cash flow is slightly under the $90 million recovery.

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